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THE FIJIAN EXPERIENCE IN THE UTILISATION OF FISH AGGREGATION DEVICES

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ACKNOWLEDGEMENT

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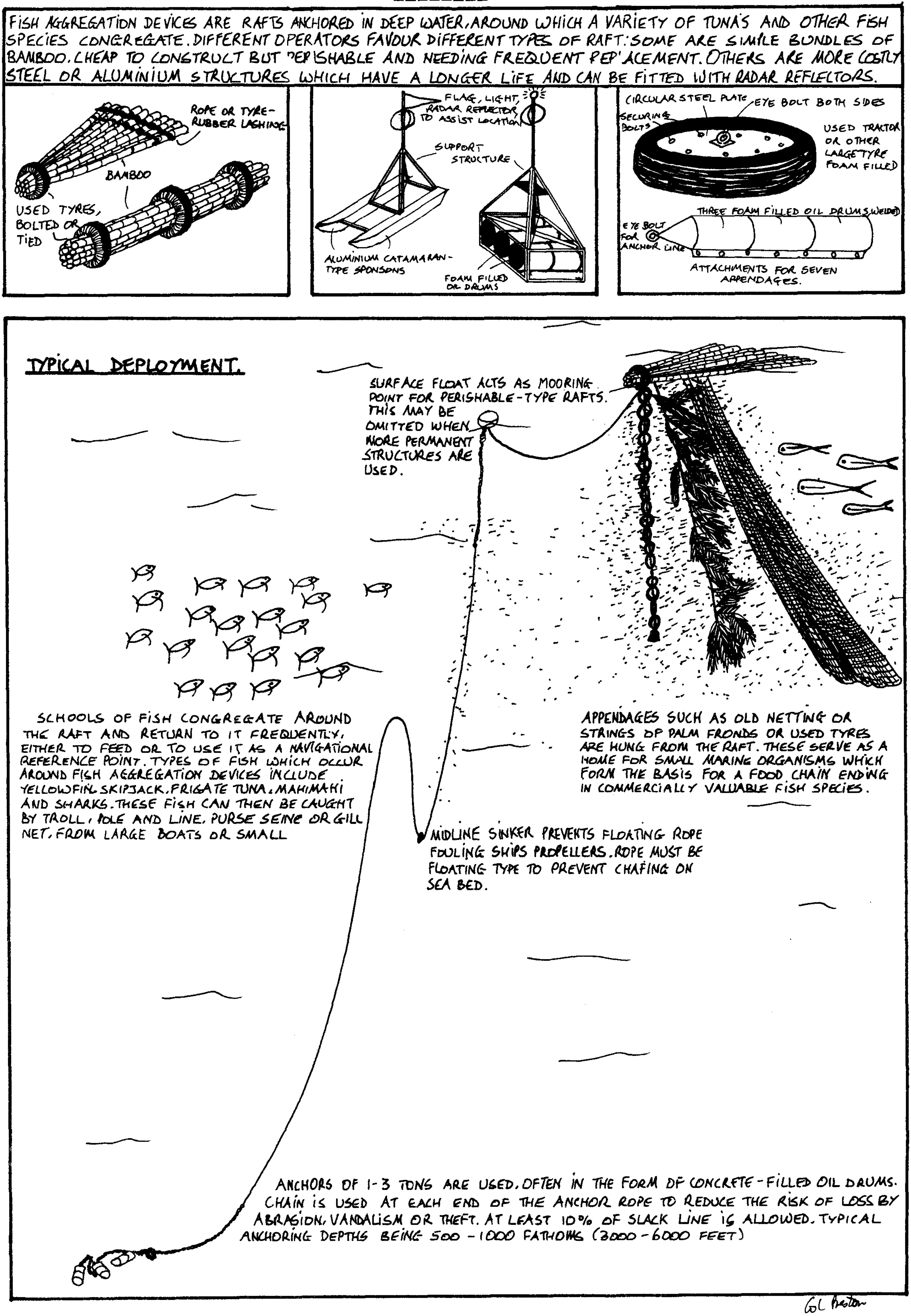
Figure 1



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INTRODUCTION

The use of anchored Fish Aggregation Devices (F.A.D.'s) in the oceanic pelagic-species fisheries of the Pacific is becomming increasingly widespread. The installation of F.A.D.'s is reported from countries as far afield as Malta, Australia, Indonesia, Japan, the Philippines, the Pacific Trust Territories, Hawaii, the U.S. West Coast, French Polynesia, Kiribati, the Solomon Islands, Papua New Guinea and Western Samoa. Despite this wide distribution of F.A.D. technology comparatively little descriptive literature exists on their utilisation, possibly because they have up to now been practical rather than research tools.

The F.A.D.'s serve a useful role in reducing searching and chasing time both for the larger industrial tuna vessels and for small commercial or subsistence fishing boats. Despite their value in this respect, F.A.D.'s pose a number of problems in their deployment and utilisation: design factors need to be optimised in terms of construction economy and durability concomitant with requirements of specific fishing methods; F.A.D.'s may increase the vulnerability of different elements of exploited fish populations disproportionately, with possible deleterious effects; and conflicts can and do arise between the different categories of user. These, and the practical difficulties presented by the variety of local conditions prevailing in Pacific nations, must be taken into account in planning the deployment of F.A.D.'s.

Over the past eighteen months insights into some of these problems have been gained during the development of a F.A.D. fishery in Fiji. F.A.D.'s were first deployed here in the second half of 1981 in order to render free-ranging tuna schools available for purse-seining, and their use has since been adopted by industrial pole and line vessels, and in artisannal commercial and subsistence fisheries. This document presents a resumé of current local information and ideas relating to the subject, which will hopefully be of value to other organistions undertaking comparable developments. Many of the suggestions and recommendations contained herein, particularly those relating to F.A.D. design and deployment, are derived from anecdotal information rather than measured and recorded fact, and should be regarded as stages in a continuing process of improvement rather than techniques and practices which cannot themselves be improved upon. In particular readers should note that much of the information contained on component specifications and prices pertains to the Fiji situation at the time of writing (July 1982) only, and this should be taken into account if the information is used in F.A.D. system design.

A number of references are made in the text to F.A.D. experiences in countries other than Fiji. These are frequently based on personal communications or unpublished documents. For this reason source material is uncited in most cases. A bibliography of published reference material can, however, be found in the final Appendix.

F.A.D. COMPONENT DESIGN

Tuna fishing vessels frequently find tuna schools close to floating logs and other flotsam. A number of as yet unconfirmed reasons (shelter, presence of food organisms, orientation factor, etc.) have been suggested for this association but the practical value, in terms of rendering schools easier to locate visually (or, if subsurface, by trolling), is clear. Purse seine vessels operating in the Pacific frequently 'label' such flotsam with radio beacons so that they can relocate the log and its likely attendant school of fish.

F.A.D.'s are man-made substitutes for naturally occuring floating objects, which appear to be similarly attractive to pelagic schooling fish. In being anchored in known locations they can improve the economics of a given fishing operation by:

1) reducing time and fuel spent in fish searching;
2) improving catch per unit of effort due to increased vulnerability or availability of the target species;
3) improving the value of the catch, in terms of species or size composition.

Additionally, F.A.D.'s serve to increase the safety factor in small scale coastal fishing operations (although this is not usually the reason for F.A.D. deployment).

The degree of investment involved in placing F.A.D.'S is clearly justified in some cases, but perhaps doubtful in others. In Fiji over 100 F.A.D.'s have been laid by commercial pole and line and purse seine operators, and, although no comparitive analyses of vessel operating economics have so far been performed, both fleets continue to invest in the activity. (For purse seining F.A.D.'s are essential, since all attempts to set on free-ranging schools have been unsuccessful). Additionally, F.A.D.'s have been deployed by the Government Fisheries Division, for the benefit of small scale commercial and subsistence fishermen. Although there are no accurate measures of production from F.A.D.'s by this fishery, it is felt that trials on a larger scale are justified, and the installation of a further 20 in areas accessible to rural fishermen is planned.

A 'typical' F.A.D., depicted in Figure 1, consists of three major components, which are:

1) Anchor. Usually an unsophisticated arrangement of weights chained together. Features to increase drag resistance, improve ergonomic efficiency, and reduce snagging potential may variously be incorporated.
2) Mooring Line. Consisting of chain terminals, rope, shackles, swivels and sinkers. The most costly component, and that which has the greatest bearing on F.A.D. residence time, the mooring line has nevertheless been largely neglected from the point of view of careful design. Apart from simple breakage through overloading, rope twist, swivel failure, midline sinker tangling, shackle corrosion, splice slippage, knotting and rope abrasion all appear to have variously contributed to raft loss.
3) Aggregator. This may comprise two seperate units, the raft, and an intermediate buoy. Some systems omit the latter feature. Rafts are equipped with appendages to enhance their attractiveness to fish. Presumably because the aggregator is the only component of the installed F.A.D. whose behaviour can be observed, it has been the subject of the greatest amount of attention by designers, despite the fact that little significant difference either to F.A.D.'s lifetime or to aggregating ability appears to result from design variations.

These three basic components will now be examined in more detail.

Anchors

Almost any heavy, dense object with a weight of 500 - 3 000 lb (depending on the pull likely to be exerted by the F.A.D. under extreme weather conditions) can be used. (It is important to consider in this context the number of boats likely to tie up to the F.A.D., e.g. for overnight fishing. Two or three small vessels can considerably increase the load on the structure and cause anchor dragging or mooring line failure. If the F.A.D. in question is deployed for use in a small scale fishery, the likelihood of a number of boats tying up is high, and must be viewed as a principal factor affecting design).

Preferred characteristics in the anchor are maximum density and irregular surface features which will resist dragging across the seabed or rolling down slopes. Conical or dome shaped upper surfaces would do much to reduce the potential for snagging or winding of the mooring line, but it is difficult to control the final orientation of the anchor on the seabed, and this has so far not been a consideration in F.A.D. deployment in Fiji. Anchors which have been used are of two simple types:

1) Concrete Filled Oildrums
A used 44 gallon drum with one end removed is filled with concrete. A mooring eye of ½" or ¾" steel reinforcing rod is set into the concrete while pouring. These are laid in groups of 1 - 3 per F.A.D., shackled along a chain terminal. Standard aggregates have a weight-in-air of about 150 lb/cu. ft. (2400 kg/m^3) which gives a single drum a weight of about 1100 lb (480 kg) in air, or about 660 lb (300 kg) in water. Later units have been elongated by welding on an additional half-oildrum, thus increasing their weight by half, and have lengths of 2" angle iron or ¾" - 1" steel bar inserted through the body prior to pouring the concrete, to increase bottom grip (Figure 2). Although no losses have so far been attributed to mooring line breakage caused by tangling around the anchor, these projections may increase the possibility of such tangling, and may also lead to rope abrasion if the terminal chain ultimately winds itself around them. However, it is difficult to reconcile the needs for high drag resistance and low tangling potential, and the latter is usually sacrificed at the expense of the former.

2) Concrete Blocks
Although just smaller equivalents to 1) above, these have the advantage that they can be moulded in various shapes and sizes to conform with the handling and other requirements of the user (Figure 3). Large numbers of small blocks are far easier to store and handle on board ship than are concrete filled oildrums, and when strung along a terminal chain they form an ergonomically more efficient anchor. The higher friction of such a system obviates the need for angle iron or other projections, but the potential for tangling is probably not much reduced due to the tendency of a string of blocks to land on the seabed in a heap. This can be avoided in practice by dropping the F.A.D. anchor first and tugging the blocks along the seabed after they land.

A potential weakness in both these anchors is the eye, made of mild steel bar, set into the concrete. This

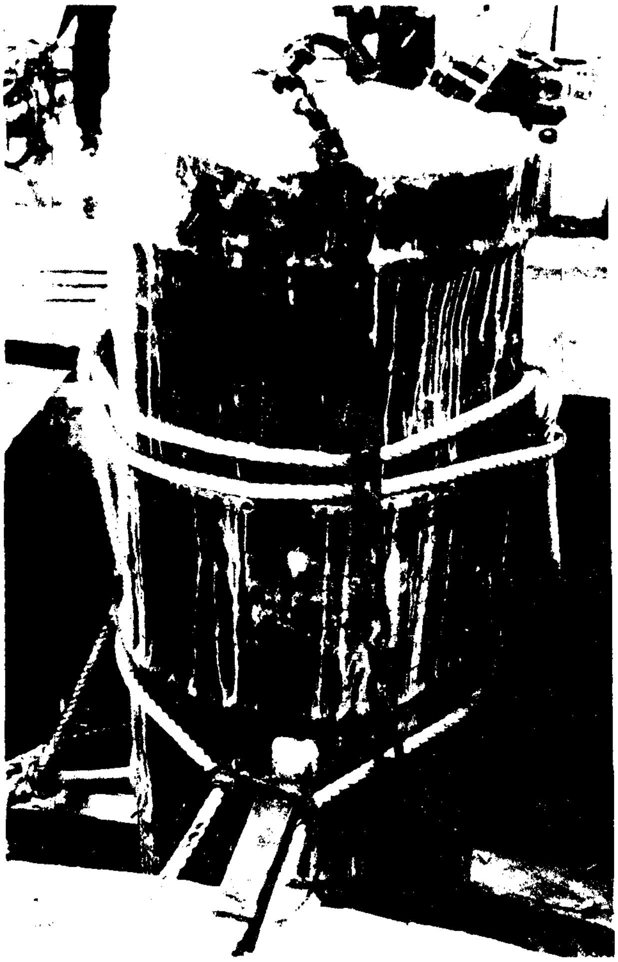
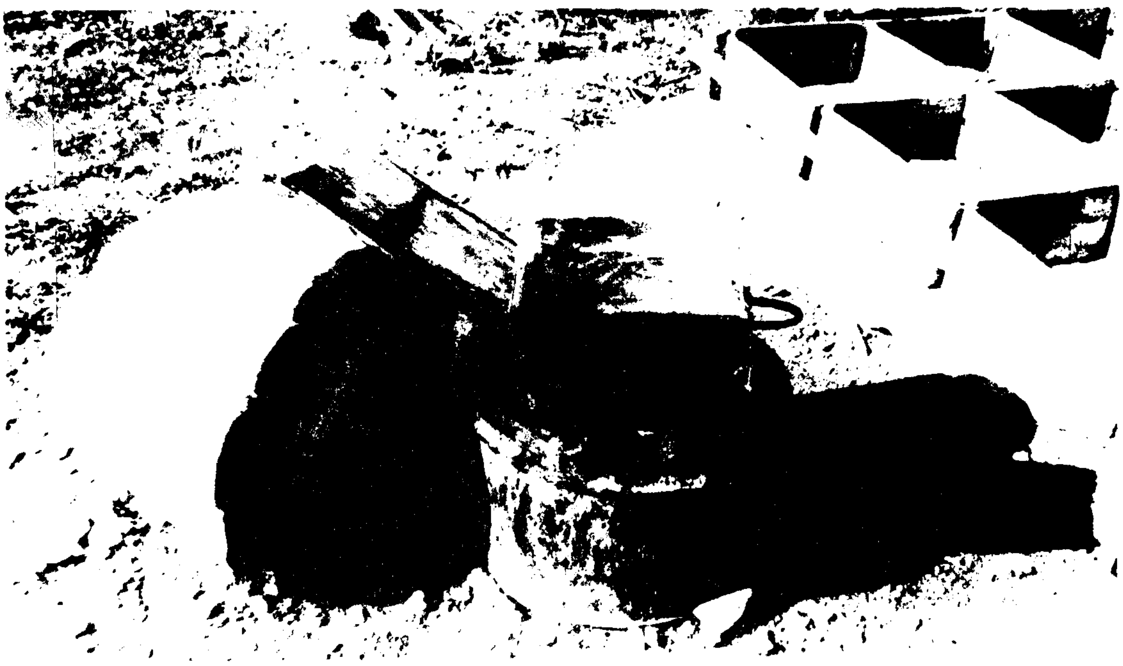


Figure 2
Concrete filled 44 gallon oildrum extended by welding on an additional half-drum. Note mooring eye set into end, and angle-iron bars to avert rolling on seabed.

Figure 3 (below)
Miscellaneous concrete filled cans used as anchor weights. Eyes are set into the concrete. In the background is a mould for casting block weights.



type of bar, which is actually reinforcing rod for concrete slabs, is not rust resistant (in fact a surface layer of rust is often encouraged to improve its grip when used in concrete structures) and is liable to corrode rapidly in sea water, particularly when subject to electrolytic action caused by directly attaching galvanised chains and shackles. A preferable system would be to anchor lengths of chain of the same type as the chain terminal into the concrete itself, and use these as the attachment point. (Figure 4a). An alternative system used by the Japanese research vessel Nippon Maru and the Inter American Tropical Tuna Commission is to embed car tyres into the concrete filled drum, thus giving a flexible, non corrosible mooring point. (Figure 4b).

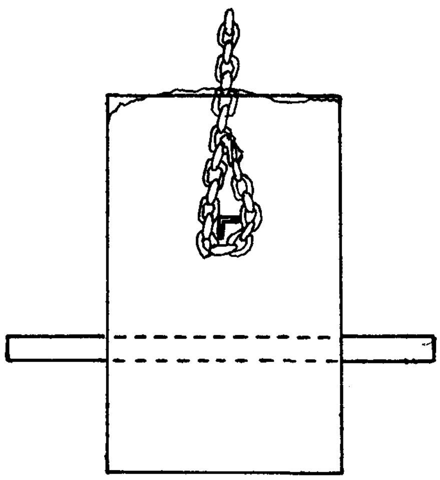


Figure 4a

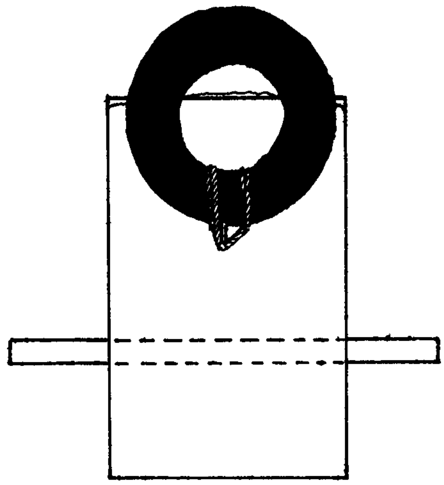


Figure 4b

Despite these considerations, no F.A.D. losses in Fiji have been positively attributed to failure of the anchor system (other than dragging into deeper water and subsequently sinking).

3) Other Types

Items used or considered elsewhere as anchors such as agglomerations of scrap iron, cement filled truck tyres, etc. have been similarly makeshift and economical. Much is determined by the local availability of materials, and many items not considered here will doubtless be used. The Hawaii Fish and Game Dept. have used old 3000 lb U.S. Navy Danforth or Baldt anchors, but most Pacific islands are not so fortunate as to have such useful items readily available.

Mooring Lines

As by far the most expensive component of a F.A.D., the main mooring line deserves substantially more attention than it is usually given by F.A.D. designers looking to economise on material costs. Cost-effectiveness frequently relates to the F.A.D.'s residence time per unit of expenditure, and by increasing the latter, the former may be extended disproportionately within certain limits.

Mooring lines are of relatively straightforward construction in that they consist of a number of coils of rope connected together, and terminating (usually) in lengths of chain or wire rope. Swivels, shackles and sinkers are incorporated into the rope at various positions depending on the anchoring depth. There are several potential weak points in the line which can contribute to its rapid breakage, but which can be safeguarded with minimal effort.

The necessary strength of the rope depends on the maximum load likely to be placed on it, but in the usually total absence of the information on prevailing wind, current, tide and surge forces at the anchoring site necessary for calculation of such load it is prudent to err on the side of safety. For this reason 16 mm diameter rope is usually considered the minimum acceptable size, with ropes of 24 mm diameter in use. Polyethylene ropes of these diameters have typical minimum tensile strengths of 2000 kg and 5700 kg respectively. Table 1 gives more comprehensive data on polyethylene ropes manufactured in Fiji, with attendant costs in June 1981.

The manufacture of ropes is an industry only recently established in Fiji, and it is now protected to some extent by tariffs on imported products. For this reason, locally manufactured ropes have been used in most Fijian F.A.D.'s, although imported varieties were incorporated into earlier units. Specifications obtained in October and December of 1980 were:

Donaghy's Ropes, New Zealand
30 x 220 m coils x 20 mm polyethylene rope,
F$3294.42 (F$499/1000 m).

Obana Rope Manufacturing Co., Japan
30 x 220 m coils x 19 mm polypropylene rope
F$3672 (F$552/1000 m).
30 x 220 m coils x 20 mm polypropylene rope
F$3977 (F$603/1000 m).

These latter polypropylene ropes were substantially stronger than the polyethylene rope currently manufactured in Fiji, having breaking strengths of 4980

(19 mm) and 5460 kg (20 mm). Breaking strength of the New Zealand manufactured rope was 3450 kg.

TABLE 1

Strength and Price Information for Some High Density Polyethylene Ropes Manufactured in Fiji*, June 1982.

Diameter (mm)	Circumference (inches)	Approximate Breaking Strength (kg)	Cost for 1000 m in June 1982 (F$)**
10	1¼	900	147.19
14	1¾	1,750	298.25
16	2	2,000	365.59
18	2¼	3,000	485.71
20	2½	4,000	627.45
24	3	5,700	941.18
28	3½	7,500	1,230.77
32	4	9,600	1,600.00
40	5	15,000	2,461.53

* Sales information, Ropes Fiji Ltd., P.O.Box 4, Nausori, Fiji.
** Maximum discount of 15% applies depending upon size of order.

Polyethylene and polypropylene ropes have so far been preferred in Fijian F.A.D.'s due to their positive buoyancy which keeps them off the seabed, thereby preventing abrasion, and because of their generally lower cost. However, other ropes with different characteristics are widely available and F.A.D. designers may prefer to incorporate more than one type into a mooring line, for reasons discussed later. Table 2 compares the strengths of various rope materials and lists other important characteristics. Quoted breaking strengths are indicators only, as the properties of rope from different manufacturers may vary widely.

As can be seen, characteristics other than breaking strength may have a bearing on the suitability of a rope for F.A.D. use. Natural fibres are completely unsuitable due to their organic nature, which makes them liable to rot, and their generally lower strength, which may decrease further under constant loading, due to their short component fibres slipping. Polyethylene is the weakest of the synthetic ropes, but has the most desirable buoyancy characteristics, is resistant to deterioration, and, probably most important, is competitive in price. Polypropylene has a higher initial strength but may suffer from elongation and consequent strength loss under continuous loading.

TABLE 2

Characteristics of Various Ropes

Rope Type	Approximate Specific Gravity	Approximate Breaking Strength (kg)*	Remarks
Natural Fibre			
Manila	1, variable	2858)	May rot or decompose in seawater
Sisal	1, variable	2600)	
Synthetic Fibre			
Polyamide (Nylon)	1.15	8300	Deteriorates in presence of mineral acids
Polyester (Terylene etc)	1.40	6300	
Polypropylene	0.91	5300	Most liable to deterioration due to sunlight. Most liable to 'creep' under constant loading
Polyethylene	0.95	3400	

* for 20 mm diameter rope.

Mooring lines usually incorporate swivels, which vary in number according to the line length and in type according to local availability and cost. In Fiji chain swivels (Figure 5a) have been used exclusively: ball bearing swivels (Figures 5b and 5c) are far superior in character but of a cost which is frequently considered prohibitive. (See Table 3). However, as weakening of the line due to rope twist (see Table 4) is probably the major natural cause of F.A.D. loss, it is unfortunate that over-economising on this component is so frequent, (even though no swivel can be expected to continue to function effectively after long immersion in sea water). Inadequate numbers of swivels are often used, and the swivels themselves frequently rust and become siezed soon after deployment. In many cases F.A.D.'s are effectively being anchored without swivels.

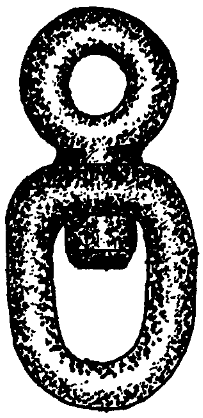


Figure 5a

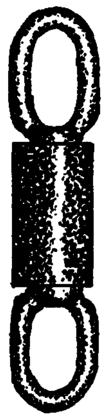


Figure 5b

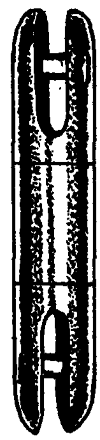


Figure 5c

TABLE 3

Swivel Specifications*

Type	Safe Working Load (tonnes)	Breaking Load (tonnes)	Cost in*** June 1982 (F$)
Chain Swivel (Figure 5a)			
9mm	0.3	4.0**	2.80
16mm	1.1	14.0**	4.95
22mm	2.75	35.0**	9.45
28mm	3.3	42.0**	22.14
Ball Bearing Swivel (Figure 5b)			
	1.0	4.5	55.25
	2.0	10.0	64.23
	3.0	14.5	77.07
	5.0	25.0	131.02
Ball Bearing Swivel (Figure 5c)			
	1.0	12.5	160.57
	2.0	22.0	231.22
	5.0	40.0	301.86

* Kondo Iron Works Ltd., Japan.
** Estimated.
***F$1.0 = ¥ 265.

Means of completely avoiding this problem usually involve greater capital outlay and may thus be unacceptable. Ideally one swivel should be placed at every junction. between rope coils, chain sections, etc., and one swivel at the point of connection of the mooring line to the anchor and the aggregator. These two junctions, particularly the latter, are the most important of all, and in no case should swivels at these points, plus at least one in the body of the mooring line, be omitted. The number of free floating aggregators recovered with only short lengths of rope attached strongly suggest that breakage due to rope twist occurs mainly very close to the junction with the aggregator. If possible it is worth investing in a single one of the more reliable ball bearing swivels for this joint, rather than several cheaper, inferior quality swivels spaced along the line.

Swivels should be incorporated into the mooring line by shackling into two eye splices lined with thimbles of the appropriate diameter (Figure 6). If available, nylon or other non-metal thimbles are to be preferred. Metal thimbles will result in electroytic action with the swivel and with each other, and contribute to the swivel's failure, even it they are of similar metals. Swivels should be generously coated in a thick layer of the heaviest quality industrial grease available, and this should be worked into the joint. This is of course, a very temporary inhibitor of corrosion only.

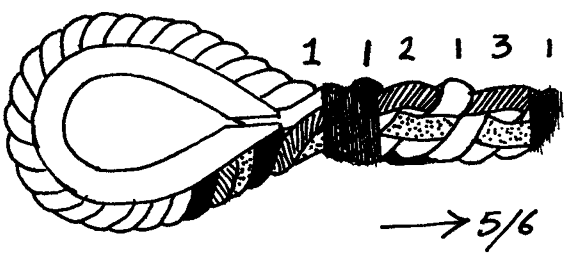


Figure 6

Junctions between rope coils which do not include swivels should be straight splices of at least 5 tucks each way for synthetic ropes and preferably more. Splices should be lashed firmly. Eye splices, with or without thimbles, should be avoided because of their potential for chafing with movement and because eye splices weaken the line more than straight splices. Knots should under no circumstances be used; a knot at any point in the mooring line will be up to 50% weaker than the rest of the line (depending on the type of rope), as detailed in Table 4. Tangling or acute twisting can also produce the same weakening effect.

A useful feature of the development of a local rope industry in Fiji is that it is now possible to obtain very great continuous lengths of rope, which will not only largely avoid the problem of splice slippage, but will also save on the amount of time and labour required to construct the mooring line. Handling difficulties largely preclude the long-distance shipping of large numbers of rope coils all still joined together, but local in-country production entails far less handling and makes this feasible.

TABLE 4

Strength Losses (%) Caused by Joints in Ropes of Various Materials

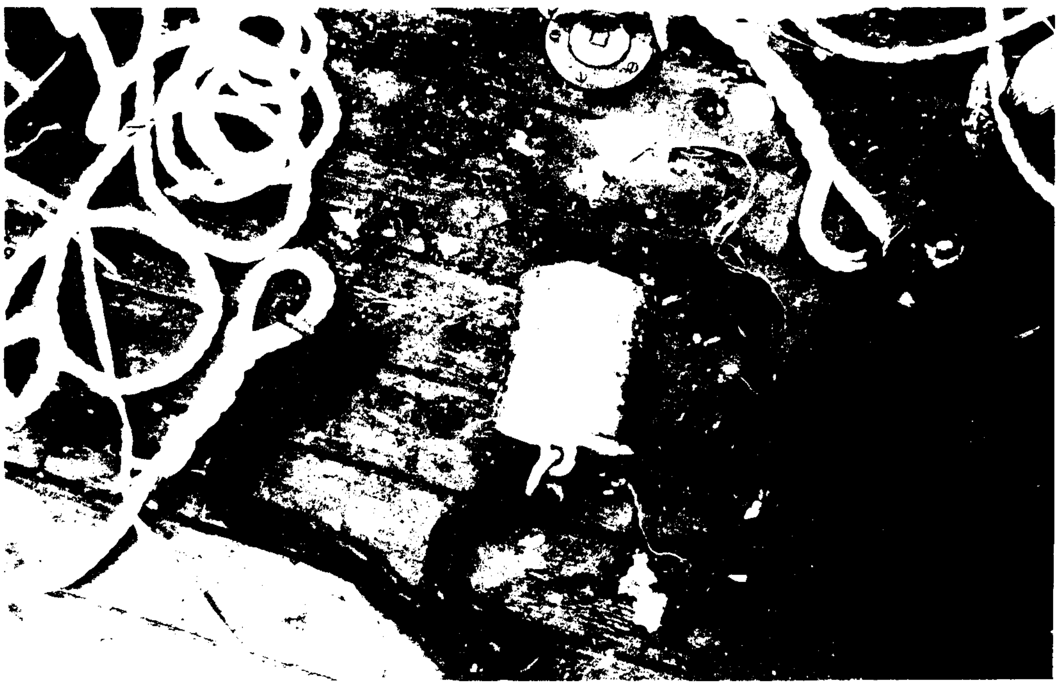
Type of Joint	Polypropylene	Polyamide	Polyester
Knots:			
Reef	47	56	47
Sheet Bend	40	48	47
Bowline	19	34	32
Clove Hitch	24	34	39
Splices:			
Straight	6	8	11
Eye	6	11	14
Eye over Thimble	4	12	19

Virtually all rope used in Fiji is polyethylene,which has a negative weight in seawater of about 1.6 kg per 18 mm x 220 m coil. This buoyancy prevents the rope from tangling on the seabed, but, unless compensated for, calm weather may allow the scope on the line to become slack enough to float at the surface, where it can be cut by boat propellors or tangle with itslef or floating debris. Sinkers are therefore necessary in the upper part of the mooring line when floating rope is used.

Frequently seen in use are single midline sinkers placed about halfway along the mooring line, with enough weight to submerge the upper portion and part of the lower portion of the rope (Figures 7 and 8). An alternative system is to use smaller sinkers at intervals along the mooring line. However, both these systems provide potential for tangling of the mooring line when a change in wind or current direction carries the raft, with the upper portion of the mooring line trailing loosely, close to or over the buoyant lower part of the mooring line. (Figure 9). In this circumstance, the two adjacent lengths of rope can easily become entangled, particularly in view of the inertia of a large sinker in such a situation.

Figure 7
Midline sinker consisting of chain lengths shackled into eye splices over thimbles.

Figure 8 (below)
Midline sinker consisting of concrete filled can with chain length passed through.



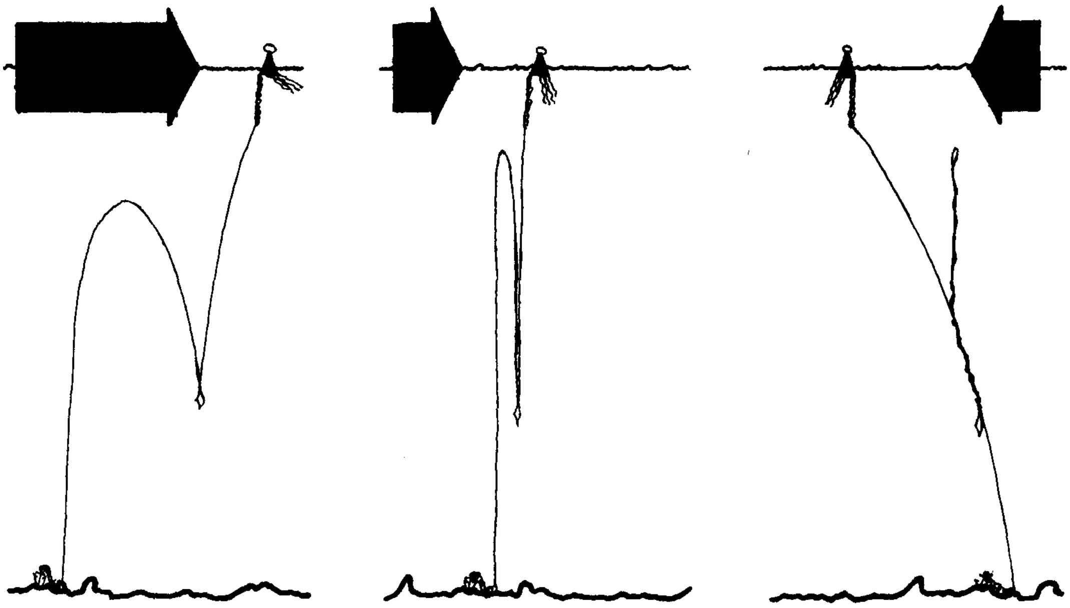


Figure 9 Tangling of the Mooring Line Caused by the Use of Sinkers.

An alternative system which largely avoids this problem has been used in the anchoring of meteorological or oceanological buoys but apparently not in F.A.D.'s. This consists of a mooring line made up of roughly equal lengths of floating (polyethylene, polypropylene) and sinking (polyamide, polyester) ropes, the former of which comprises the lower portion of the mooring line (see Figure 10.). This system may be more costly, but it avoids the use of heavy objects as sinkers and largely eliminates the potential for tangling due to inertia. A usual prerequisite, however, is that the approximate anchoring depth be known before laying the F.A.D. so that the correct rope proportions can be estimated. As it is sometimes the case that the water depth at the F.A.D. site is not known even approximately until the time of laying, and that major adjustments to the construction of the mooring line are usually inconvenient or impossible at this time, it seems probable that sinkers will continue to be widely used.

This being the case, three or four small sinkers along the line are preferable to one large one, although they are more trouble to construct. Unless of high quality, structural- standard materials, sinkers should preferably not be an integral part of the mooring line as they are in Figures 7 and 8. Sinkers usually consist of old chains, blocks of concrete etc., in which case these should be lashed on (or spliced into the lay of) the rope at points where they cannot interfere with swivels or other rope fastenings. All sinkers, particularly chain sections, should be attached at one end only, and allowed to hang free, thus preventing pulling of the mooring rope into a loop which can tangle or knot. (Figure 11).

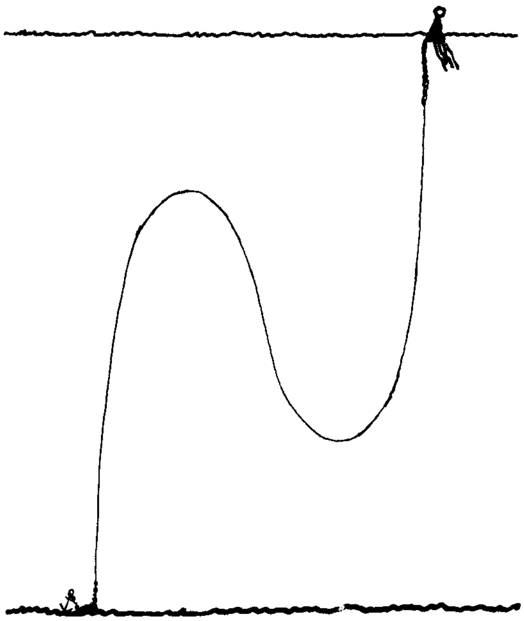


Figure 10

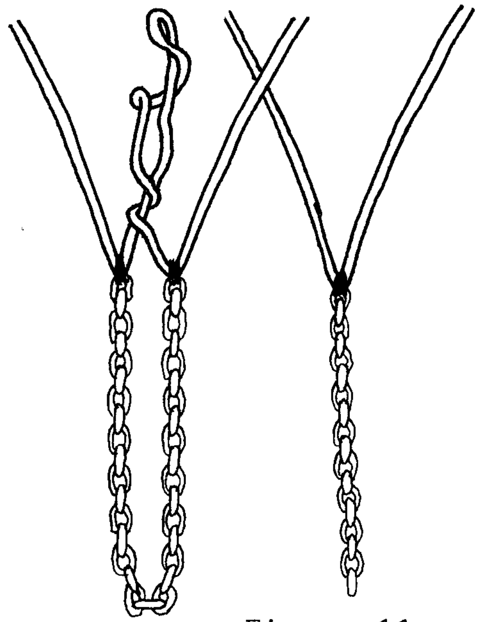


Figure 11

It is usual for mooring lines to terminate in lengths of chain or cable at each end. This goes a long way towards preventing chafing and at the upper end may assist in deterring attempts at vandalism or theft of F.A.D. components. Terminal chains are attached to swivels and ropes by shackles, or, less frequently, split links. Clearly these components must conform to the strength requirements of the rest of the mooring line. Although the specified breaking load of even a small shackle is much higher than an equivalent diameter rope (see Table 5) deterioration of metal components through corrosion over several years may have to be taken into account. Shackles with screw-in pins have a tendency to work loose, so the safety shackle type with a facility for a locking nut on the pin is preferable. (Figure 12)

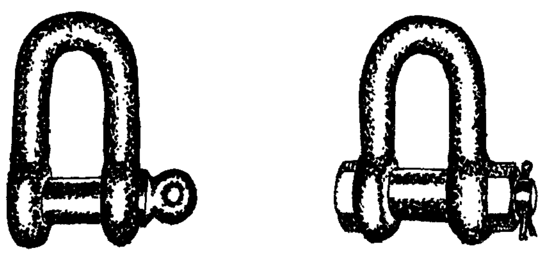


Figure 12

The pin should also be firmly secured by tying with plastic coated wire, hard monofilament or tough braided twine; or, better, by epoxy or fibreglass coating the shackle.

TABLE 5

Mild Steel Shackle Specifications, With Indicative Costs For Fiji, June 1982

Pin Diameter	Safe Working Load (kg)	Breaking Load (kg)	Approximate Retail Cost in Fiji (F$) June 1982
3/8"	330	2,400	$2.50
7/16"	495	3,600	-
1/2"	660	4,900	$3.00
5/8"	990	6,400	-
3/4"	1,540	10,000	$5.30
7/8"	2,200	14,400	$6.50

The action of the upper chain terminal is relatively easily observed, its configuration depending upon the type of aggregator to be used. If possible, a 10 m chain bridle to the aggregators should be attached via a high quality swivel, to a 25 - 50 metre single chain section, which is in turn attached to the mooring rope, preferably by a swivel. (See Figure 13). This system

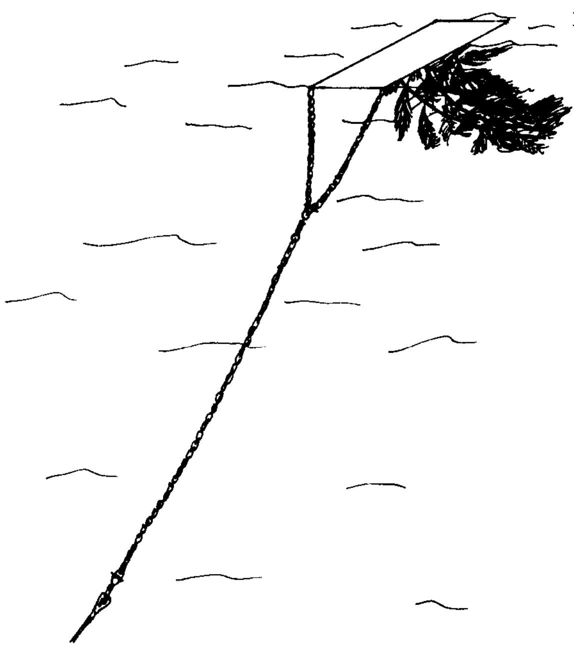


Figure 13

not only makes it difficult for the crew of small boats to pull up the mooring line by hand (if they have a winch such action is impossible to prevent), but greatly stabilises the aggregator and prevents much of the rotation which may otherwise lead to rope twist and possible breakage. The upper chain terminal provides enough weight on the swivel located between itself and the aggregator bridle to improve the swivels turning action. Small amounts of rust or other factors resulting in stiffness in the swivel may prevent its free movement in response to rotation of the aggregator when attached directly to the rope of the mooring line. A heavy chain section, however, will usually provide enough inertia to break the swivel free, particularly if a high quality swivel is used, as recommended, at this point.

As the forces acting on an F.A.D. mooring line are strongest near the aggregator, and tend to be concentrated in the upper 100 m, a long chain terminal is preferred in order to resist these forces. F.A.D.'s with a short upper chain terminal, or none at all are usually found with only short lengths of mooring rope still attached if they break loose. Clearly, if a long chain is used, the flotation of the buoy or aggregator must be adequate to carry the chain's additional weight, which is indicated along with other specifications in Table 6. 13 or 14 mm chain is recommended for mooring line applications.

TABLE 6

Approximate Chain Specification Indications

Diameter (mm)	Approximate Breaking Load (kg)	Approximate Safe Working Load (kg)	Approximate Weight (kg/100m)	Approximate Cost (F$/100m)	
6	1,380	350	75	214*	
8	2,450	630	135	236*	
9	3,100	790	175	252**	
10	3,800	1,000	225	391*	
13	6,500	1,600	380	778*	329***
14	7,500	1,900	425	530**	
16	9,800	2,500	580	-	
18	12,400	3,100	730	-	

* Local retail cost, Suva, June 1982
** Japanese supply company, FOB Japan, November 1980
*** Japanese fishing company operating in Fiji, buying via its head office in Tokyo, FOB Japan, November 1981.

The in situ behaviour of the lower terminal chain is difficult to deduce, but it appears that this section is not usually the cause of mooring line failure. So far there is no positive evidence in Fiji of F.A.D. loss directly due to anchor failure, other than by dragging due to inadequate anchor weight. It is probable that the longer the chain, the less likely it is to become completely fouled on the anchor or bottom features and subsequently induce rope chafing at this point. Chain lengths of 10 - 20 m from the point of attachment of the innermost anchor block appear to be adequate.

Aggregators

The third major F.A.D. component, the aggregator, is much less expensive to construct, more easily replaced, and less liable to contribute to the loss of the whole structure than the mooring line, but has received substantially more design consideration, presumably because it is the part of the F.A.D. which is seen, and whose properties are most easily observed.

Most variations in aggregator design are aimed at economy or ease of production or handling. Little consideration is generally given to its effectiveness in aggregating fish. Judging from the wide variety of floating objects with which pelagic fish schools are found in association (logs, loose assortments of weed,etc.), almost anything will serve the purpose of aggregator, although it does appear that appendages, described in detail later, play a major role in improving the effectiveness of F.A.D.'s. Whether this is due to the suggested causes of shelter for the pelagic fish themselves or for the prey species, provision of an orientation cue, some combination of these, or for entirely different causes, is unknown, but in view of the wide variety of materials and configurations which have proved effective, it is appropriate that attention is currently focused on gross improvements in the practical aspects of aggregators (durability, ease of handling and cost) rather than fine improvements in performance based on a poor knowledge of the F.A.D.'s biological significance.

Two aggregator systems are currently in use in Fiji - one which incorporates an intermediate buoy, and one which omits this feature. The former of these is preferred by purse seine vessels, which need to disconnect the raft from the buoy (see Figure 32) to allow encirclement of the raft and its attendant fish schools by the net. Such a system is also preferable when low-cost rafts are used, as it enables easy disconnection and replacement of the raft when its condition deteriorates. This arrangement can also be useful in preserving mooring lines in areas liable to extremes of wind or current, by incorporating a weak link of lower strength rope between the intermediate buoy and the raft. As the raft has much more water resistance due to the surface area of its appendages than the buoy, and as its loss alone is preferable to the loss of the entire F.A.D., this system is to be preferred in, say, strongly tidal areas such as straits between islands, where high speeds of water movement may be expected.

Systems which omit the intermediate buoy usually incorporate a strong and durable raft which is not expected to deteriorate significantly, as raft replacement is considerably more difficult.

The following paragraphs describe some currently used or proposed raft designs.

1) Intermediate Buoys

Figure 14
Intermediate buoy - canvas wrapped, expanded polystyrene or other chips inside.

Figure 15
Intermediate buoy - hollow polythene float.

Intermediate buoys used as attachments for perishable rafts have consisted of prefabricated floats such as those pictured. These are only moderately expensive (type similar to Figure 14, F$35 FOB Japan in August 1981: type in Figure 15 F$50 FOB New Zealand, January 1982) but are a target for thieves as they are useful in a variety of ways to boat owners. The polythene type, being hollow, may be accidentally or deliberately punctured.

2) Bamboo Bundle Raft

Ten to twenty bamboo logs, 15 - 20 feet long and 3 - 6" in diameter are tightly packed into two old car or truck tyres, and lashed with chain and rope fragments and offcuts. Some have two to several hardwood logs, of four-inch square or circular section, incorporated for additional strength, This type of raft is easily damaged and tends to work loose due to frequent movement, and is therefore usually anchored to an intermediate buoy. The original versions of this raft were unnecessarily large (Figure 16) and consequently costly and hard to handle, but they have since been scaled down to a more appropriate size (see Figure 17).

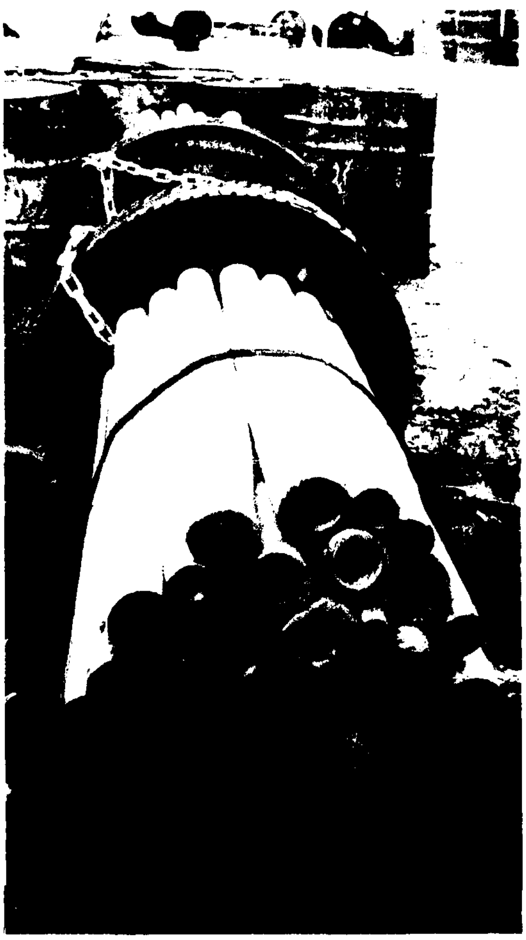


Figure 16
Bamboo bundle raft.
Original model.

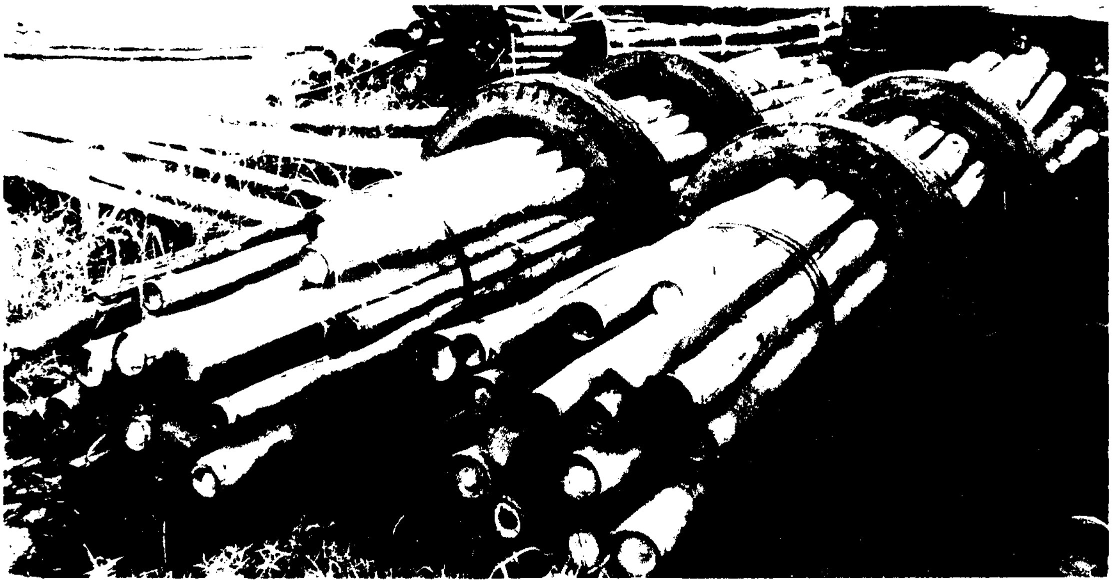


Figure 17
Bamboo bundle rafts, Later models, reduced in size.

3) Bamboo Fan Raft

Figure 18
Bamboo fan rafts.

Ten to twenty bamboo logs are forced tightly into a car or truck tyre at one end, and lashed along a bamboo crossbar using old long-line rope at the other (Figure 18). The tyre is secured in place by rope oddments, and serves as the attachment point for the rope connecting the raft to the indermediate buoy, which is tied on. This type is easier to handle than the previously described bundle raft and the bamboos are not so liable to work apart.

A number of early rafts of this type were quickly lost due to chafing of the connector rope on the edge of the tyre at the point of connection. This has since been overcome to some degree by passing a sleeve of plastic or rubber hose over the rope at this point. (See Figure 19).

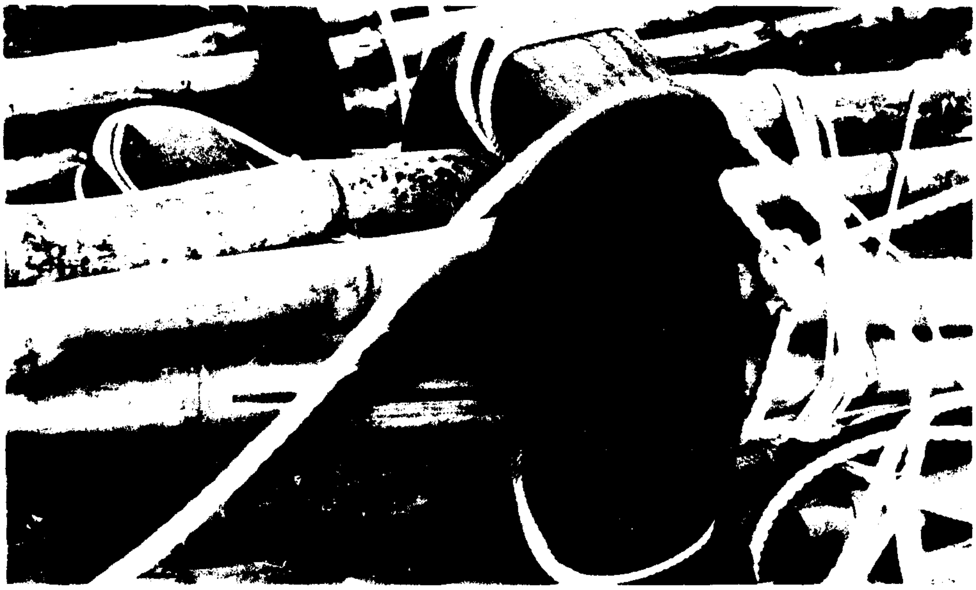


Figure 19
Protective sleeve of plastic hose around connector rope.

More recent versions of this raft have had the connector rope arranged as a self tightening choker, by looping it around the bamboo raft body in a series of slip knots, so that increased tension on the rope, such as in periods of rough weather, will hold the raft together more tightly. (See Figure 20). It is, however, impossible at this stage to assess the value, if any, of this arrangment. It may be that the weakening of the connector rope caused by the slip knots is more likely to contribute to raft loss than the bamboo's working apart.

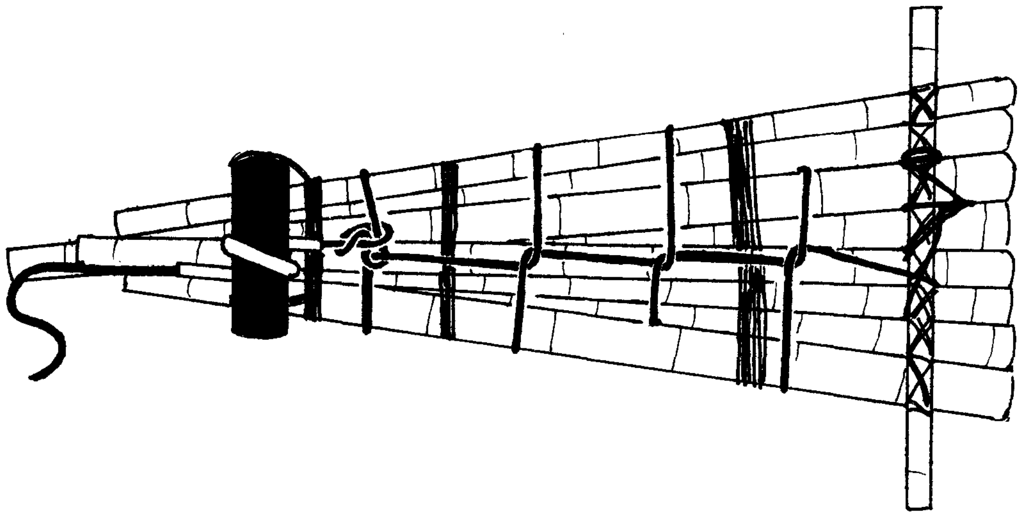


Figure 20
Self-tightening choker rope on bamboo fan rafts.

Visual location of this and the preceding model is rendered much easier if a small flagpole buoy is attached on a short length of rope to the free end of the raft. A second flagpole float should be attached directly to the intermediate buoy, so that both components can be seen if the raft should break loose.

4) Oildrum 'Box' Raft

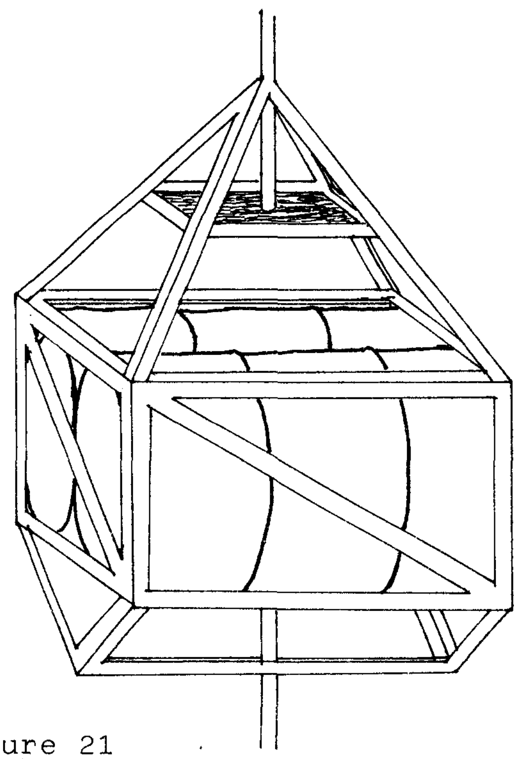


Figure 21
Oildrum 'box' raft.

2 - 3 44 gallon oildrums are welded into an angle iron framework, 2" steel piping being incorporated above and below as mast and counterweight, supported by a pyramidal frame of angle iron. Mooring is to the lower piece of steel piping, by a shackle, and the upper can accomodate a radar reflector and/or light. Due to the potential for rapid corrosion, rafts of this type should be foam filled and well painted, preferably by sand blasting and epoxy coating. Completely effective corrosion prevention is, however, virtually impossible, particularly as the necessary welding introduces a

number of electrolytically active metals into contact with each other.

Construction of this type of raft is labour intensive, and the raft itself is heavy and of an awkward shape. Two have been deployed in Fiji, both of which suffered rapid corrosion, particularly to the drums themselves. One is, however, still in service after 18 months, and does not yet appear to be holed. The other was lost shortly after installation and discovered later washed up on a rocky shore 120 miles away, irreparably punctured. Holing may have been due to battering while grounding rather than purely corrosive action.

5) Oildrum 'Rocket' Raft

Figure 22
Oildrum 'rocket' raft, laid on fishing platform of pole and line vessel prior to installation. Note diamond-shaped radar reflector, and mixture of tyre-wall and packing strap appendages (see later).

Three (or occasionally more) 44 gallon oildrums are welded together end to end, foam filled, sandblasted and epoxy coated. An iron flange welded to two or three circular clamps is bolted tightly around the drums, and holes in this act as attachment points for the mooring rope and appendages. A mast, supported by two pieces of ¾" reinforcing rod, is welded to the oildrums before painting (Figure 22).

A problem with this raft has been the fragility of the mast, which easily breaks off, hindering subsequent location. The design also incorporates a substantial amount of welding, which is always to be avoided because of the electrolytic action to which welds will be subjected.

In describing the two preceeding rafts, reference has been made to foam-filling oildrums. This is done by mixing equal volumes of two commercially available resins, which react to produce a liquid foam of about 25 times the total volume of the original components. Setting of the foam occurs about 30 seconds after mixing, so foam filling of canisters should be performed in a series of small volumes to ensure good mixing of the resins and its penetration into any irregular cavities.

The total cost of one 44 gallon drum of each resin in Suva in June 1982 was approximately F$1450. This quantity generates 11 m^3 of foam at a cost of about F$130 m^3, or, enough to fill fifty drums for F$30 each. Foam filling one raft consisting of 3 oildrums thus costs about F$90 - 100, which is a small proportion of the total cost, and justified in that the foam will prevent water entry into a damaged or holed raft for a long enough time to permit the detection of the damage and its correction. (The foam contributes no additional buoyancy to a sealed container until it is subsequently holed).

It has been proposed that by incorporating loose floats, with enough total buoyancy to support the raft appendages and mooring line, inside an otherwise empty 'rocket' raft, a system could be devised whereby a holed raft would upend itself, thereby giving a clear indication of damage which might otherwise go unnoticed. This suggestion has so far not been put into practice.

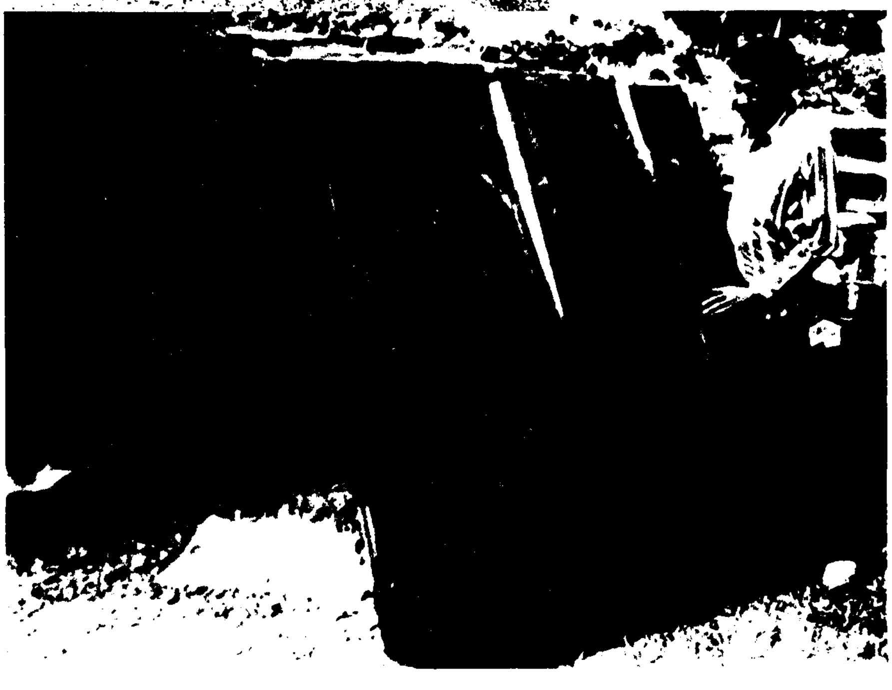
6) <u>Aluminium Catamaran Raft</u>
   This raft is imported prefabricated from Western Samoa, after which wooden side panels, etc., may be added. The anchoring bridle and triangular apex serve to keep the raft correctly orientated to wind and current, and it is easily spotted due to its high mast. The raft appears durable, but costs some F$850 exclusive of freight. (See Figure 23).

7) <u>Polythene Float Raft</u>
   These have been recently imported from New Zealand at a cost of F$100 each, but have not yet been deployed. While requiring minimal construction work, it is felt they will not be strong enough to last long due to the thinness and softness of the plastic. They should therefore be viewed as belonging to the same category of 'expendable'

rafts as the bamboo types described earlier.

<u>Figure 23</u>
Aluminium catamaran raft, imported from Western Samoa - the sealed hulls are foam-filled.

<u>Figure 24</u> (below)
Polythene float for use as a raft.



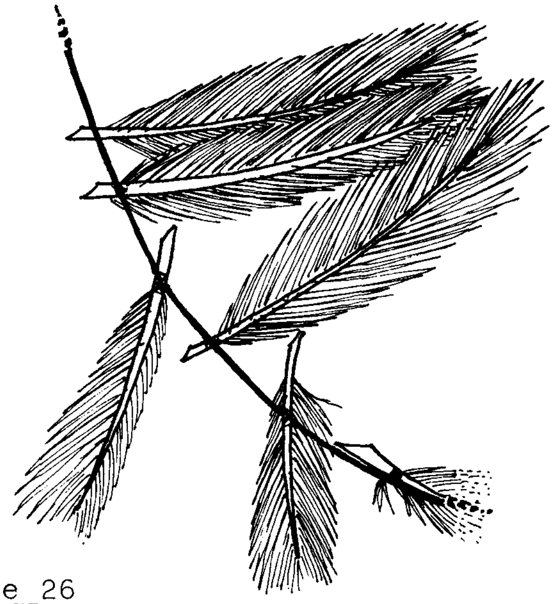
8) Truck Tyre Raft

Figure 25
Skidder tyres for use as a raft.

A raft design used in Hawaii but not so far in Fiji consists of a used truck or other large tyre, foam filled, with steel plates bolted over the tyre apertures, and with a mast and counter weight post of steel piping inserted. Some used tyres from earth-moving machinery at one of Fiji's hydroelectric developments have recently been obtained, and this type of raft will be trialled during 1982/1983. Advantages are low cost, resistance to corrosion (only small amounts of metal are involved) and reduced danger to shipping in the event of a collision.

The appendages used on aggregators to enhance their attractiveness to the fish come in many shapes and sizes as do the rafts themselves. Some, such as bundles of palm fronds tied onto a rope, are rapidly perishable but virtually free, easy to construct, and can be tied to the raft as the old ones decay and fall off. More durable, maintenance free appendages, such as those made of plastic parcel strapping threaded through ropes, are more costly to construct but can be relied on to last the lifetime of the raft, and are more suitable for long-life aggregators.

9) Palmfrond Appendages



Palmfronds lashed or tied onto old longline rope represent probably the cheapest appendage used in Fiji. These must be replaced every month or two, but are easily constructed and attached. (See Figure 26).

Figure 26

10) Tyrewall Appendages

Car tyres are cut in half and threaded onto ropes, as shown in Figure 27, to prevent slippage. This appendage is more durable, but labour intensive and requires a supply of car tyres which may be unavailable. (See also Figure 22).

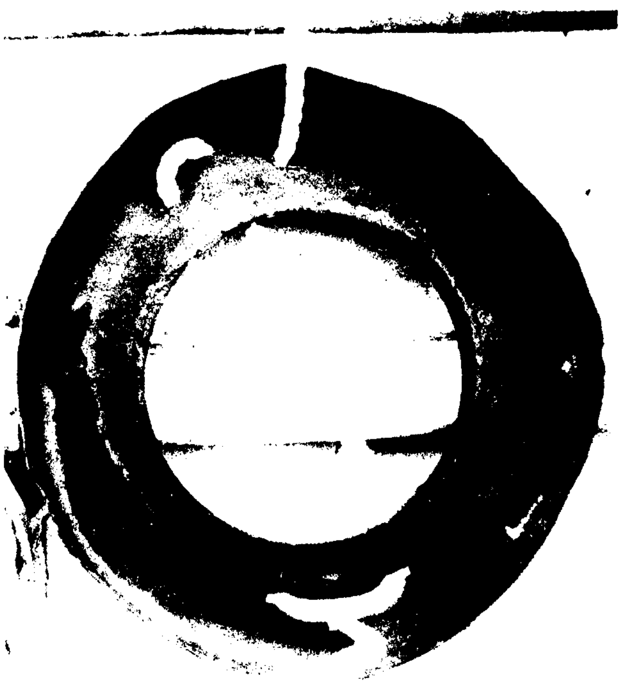
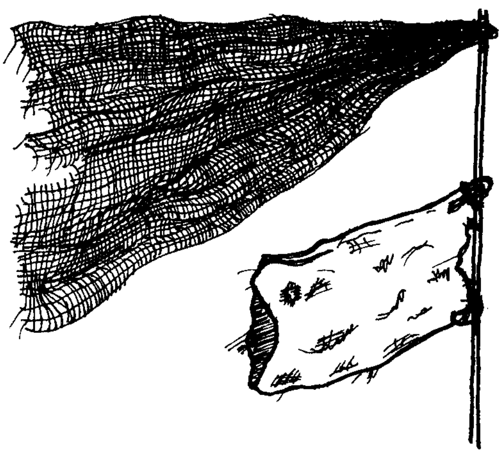


Figure 27
Car tyrewall threaded onto rope as part of an appendage.

11) Netting Appendages

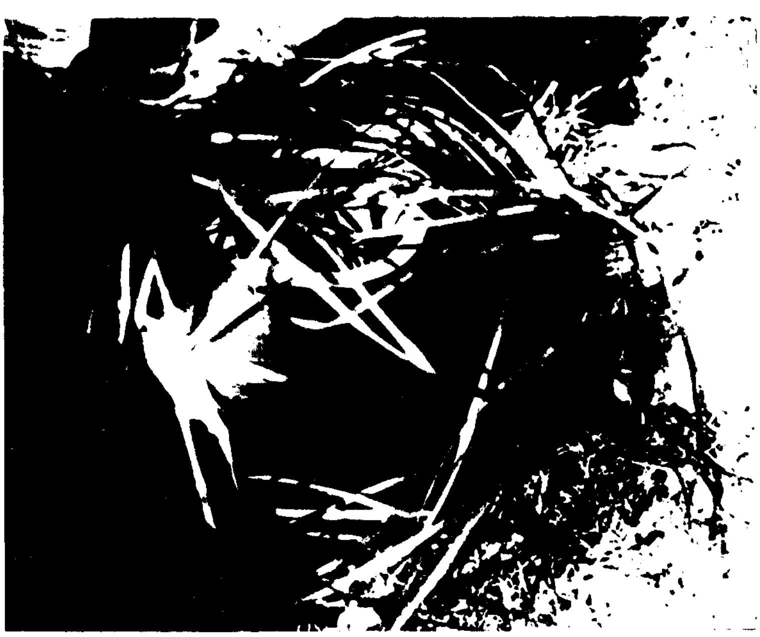
Old pieces of net, rope, and sack are tied or threaded onto a rope. This is a more durable



version of 9), but the fibres of the netting, etc., particularly natural fibres, will ultimately decay. There are reports from other countries of fish being gilled in netting appendages, and subsequently attacked by sharks, causing damage to the appendage.

Figure 28

12) Packing Strap Appendages



Lengths of industrial package strapping (Figure 29) are threaded through the lay of ½" or thicker rope, to form artificial palmfrond-like streamers. Construction is labour intensive but these appendages are extremely durable and have the advantage that the lengths of strapping can be very long, thus creating a very large surface area for shelter or growth of organisms (Figure 30). Almost all F.A.D.'s in Fiji now incorporate this type of appendage.

Figure 29
Industrial package strapping used in appendages.

An appendage reported from Hawaii by Matsumoto et al. (1981) but not used in Fiji consists of net and rope segments laid horizontally between two lengths of rope kept apart by spreaders made of steel piping (Figure 31).

Figure 30
Oildrum 'rocket' raft with tyrewall and packing strap appendages already attached and stacked on top.

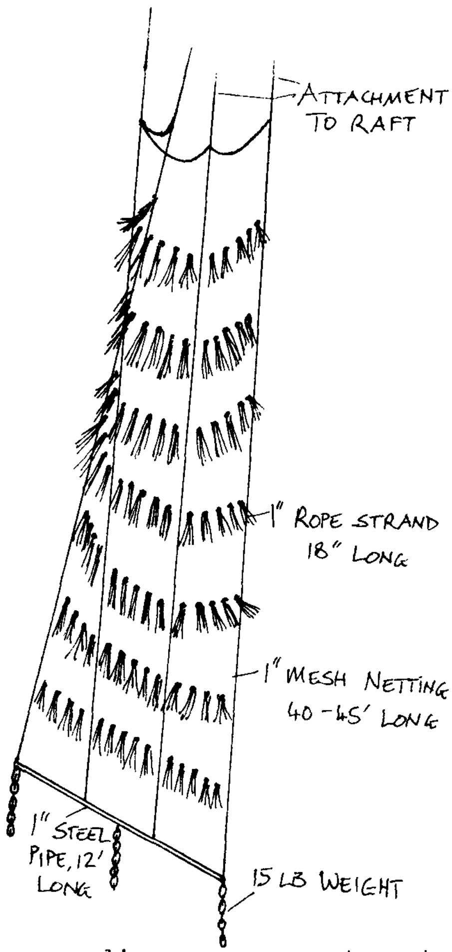


Figure 31
(After Matsumoto, Kazama, and Aasted, 1981).

The preceeding paragraphs should give an impression of the type and range of materials suitable for F.A.D. construction. Doubtless different local situations will produce an equally wide range of novel designs.

F.A.D. SYSTEM DESIGN

Major variations in design of all three basic F.A.D. components (anchor, mooring line and aggregator) allow a large number of possible combinations in the final model, each of which has different characteristics of cost, durability, ease of handling, and effectiveness. For most organisations involved in laying F.A.D.'s, (who may be fishing companies, village groups, or fisheries development bodies) cost is a major criterion in determining the system selected. Cost indications for the various components have been presented in the preceding chapter. Other criteria will be discussed in the following paragraphs.

Certain fishing methods impose specific requirements on the F.A.D. system. In Fiji, many F.A.D.'s have been laid for purse-seine fishing of skipjack and yellowfin tuna. The purse seine vessels carry a floating raft, made of oildrums, supporting a platform to which are fixed a generator and an arrangement of underwater and surface lights providing about 4000 w. This light raft is attached to the F.A.D. raft in the evening, and the lights switched on at dark. Before dawn the F.A.D. raft is disconnected from the mooring line and, still attached to the light raft, is allowed to drift off the mooring site. The lights (presumably) draw off the rafts resident population of baitfish and, if present tuna, which can be detected by echo sounder. The net is set around the two rafts, which are winched out before the net is fully pursed. After brailing, the F.A.D. raft can be repaired, appendages restored, etc. before re-attaching to the intermediate buoy, which is left in place.

It is thus clear that this fishing method requires a F.A.D. system which allows the raft to drift free of the mooring line. The method of using the F.A.D.'s allows easy repair of rafts, and favours light-weight, easy-to-handle models. For these reasons intermediate floats and bamboo bundle or fan rafts are used in this operation, with little emphasis placed on long-term durability.

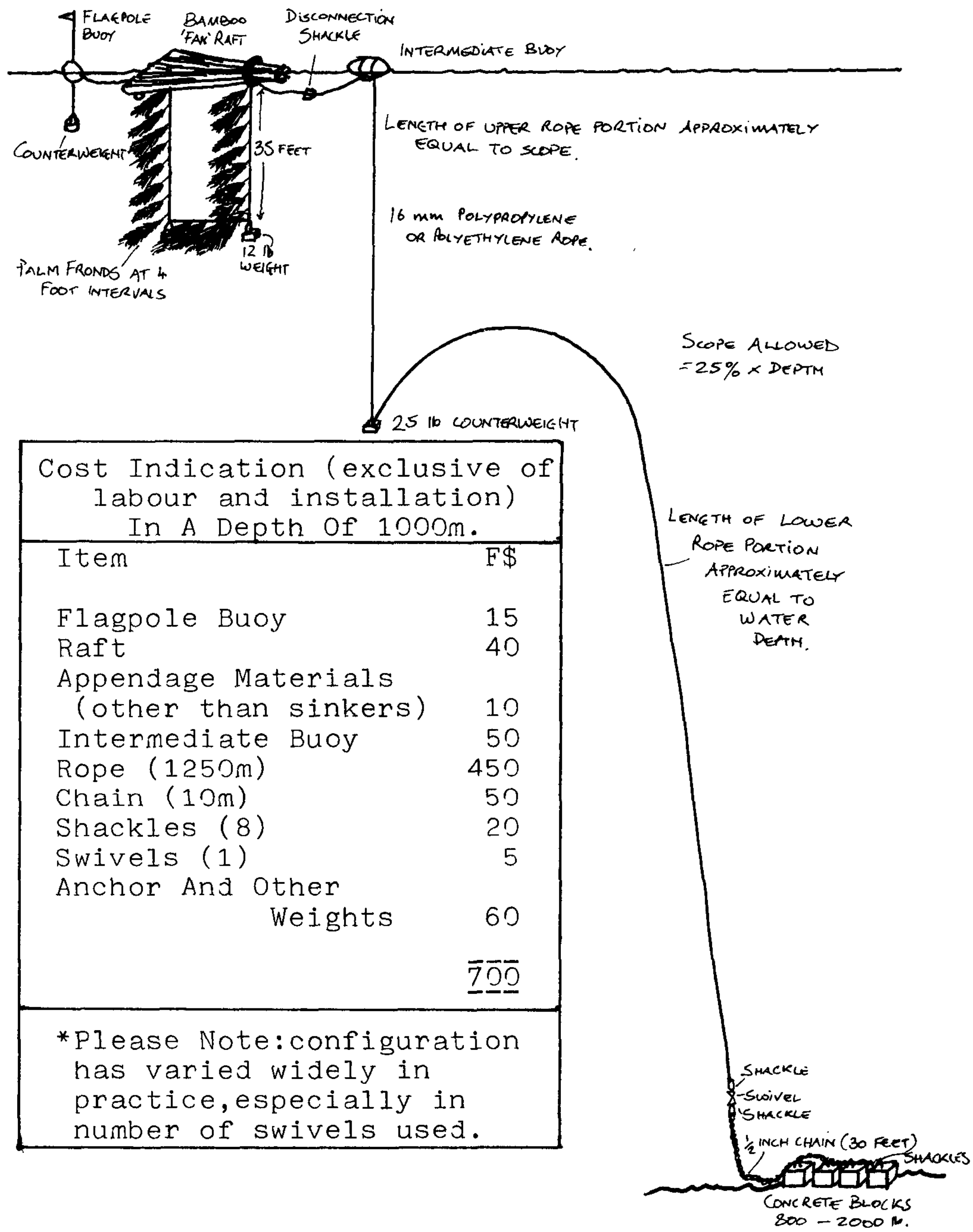
An additional consideration here is that the tuna may not be drawn off a raft by the lights, in which case it will be necessary to set the net around the F.A.D. system, even though this is likely to uproot or destroy the mooring line. While undesirably wasteful, the destruction of a F.A.D. which has cost about F$1000 in order to catch up to 50 tonnes of fish worth some F$900/tonne is quite rational. Nevertheless, this approach gives an additional incentive to minimise

F.A.D. construction costs,and to avoid unnecessarily strong components which may result in damage to the more costly purse seine net and lost fishing time,even if this reduces raft life expectancy somewhat.

This type of purse seining thus favours low-cost,short lived F.A.D.s such as those depicted in Figure 32.The cost indications given in this and in Figures 33,34 and 36 should be regarded as very approximate guidelines only.

Chapter 5 contains an evaluation of the performance of this design.

Figure 32



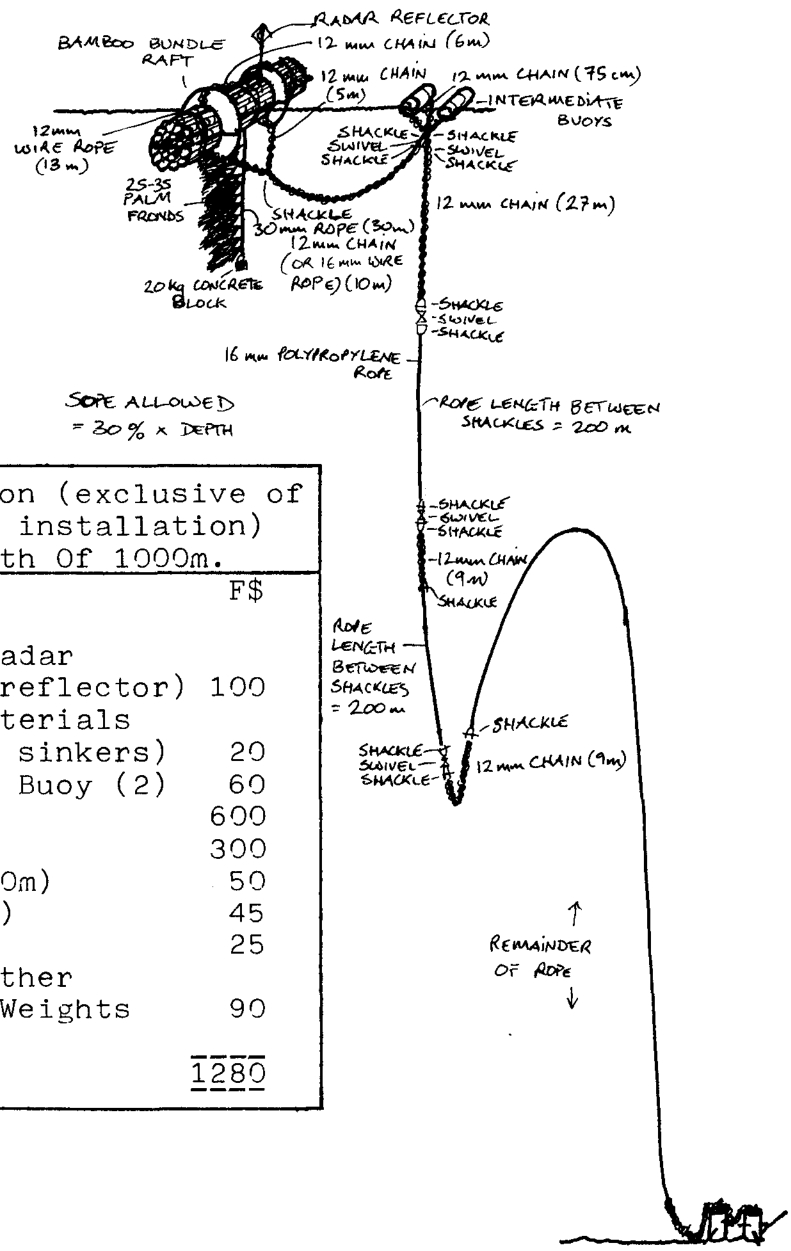
Cost Indication (exclusive of labour and installation) In A Depth Of 1000m.

Item	F$
Flagpole Buoy	15
Raft	40
Appendage Materials (other than sinkers)	10
Intermediate Buoy	50
Rope (1250m)	450
Chain (10m)	50
Shackles (8)	20
Swivels (1)	5
Anchor And Other Weights	60
	700

*Please Note:configuration has varied widely in practice,especially in number of swivels used.

Other fishing methods are both less potentially destructive of F.A.D.s and do not require raft disconnection.Pole and line fishing is conducted as on open water schools,and imposes no specific constraints on F.A.D. system design other than those dictated by sensible business practices, which entail minimum expenditure concomitant with minimal maintenance requirements.Visual markers on F.A.D.s are not necessary for vessels equipped with satellite navigation equipment.Those vessels aiming to locate F.A.D.s by radar usually attach a mast bearing a metallic reflector.Figures 33 and 34 show F.A.D. systems used by two pole and line vessel operating companies in Fiji.

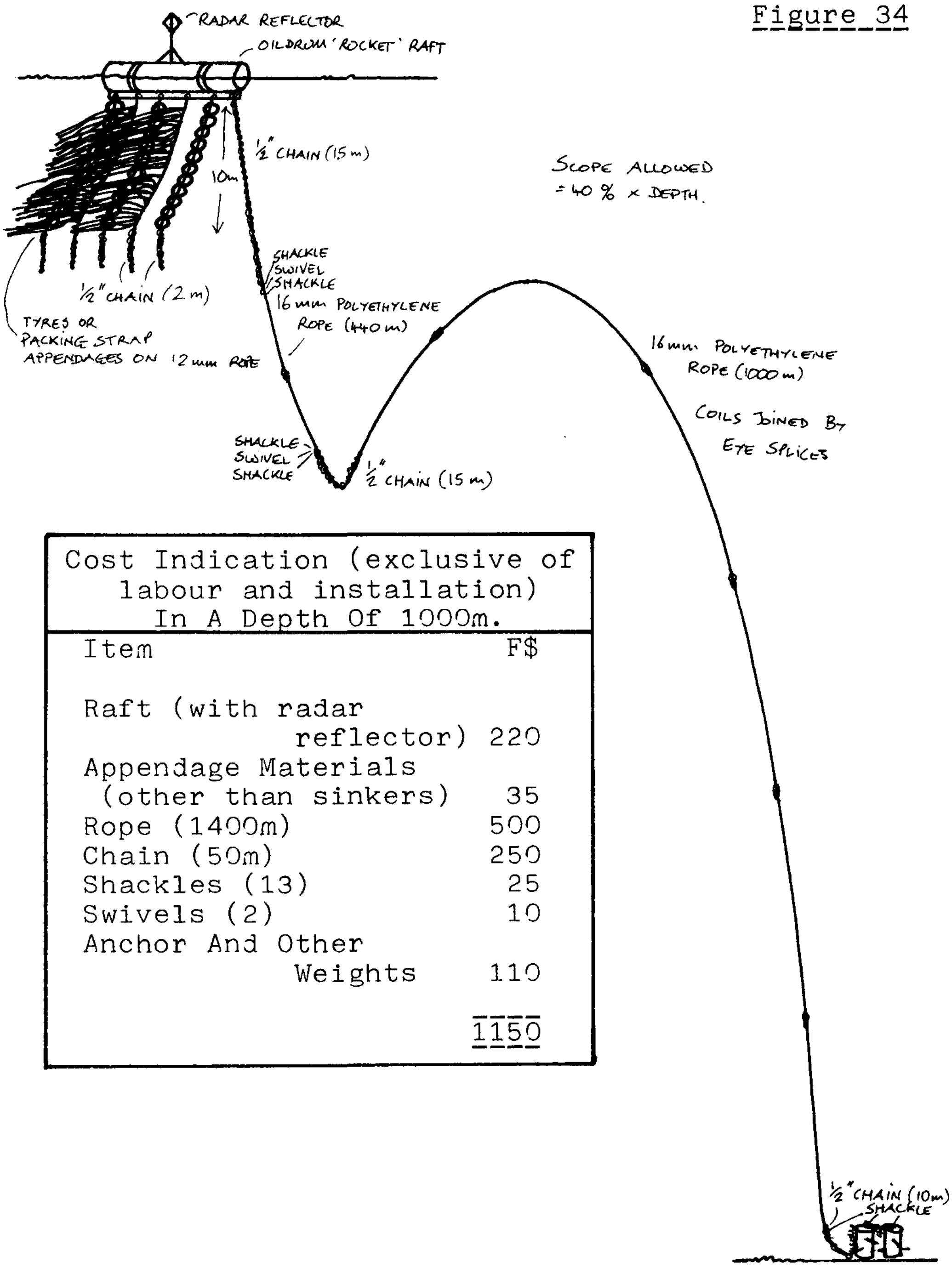
Figure 33



Cost Indication (exclusive of labour and installation) In A Depth Of 1000m.

Item	F$
Raft (with radar reflector)	100
Appendage Materials (other than sinkers)	20
Intermediate Buoy (2)	60
Rope (1300m)	600
Chain (94m)	300
Wire Rope (40m)	50
Shackles (21)	45
Swivels (5)	25
Anchor And Other Weights	90
	1280

Figure 34



Cost Indication (exclusive of labour and installation) In A Depth Of 1000m.

Item	F$
Raft (with radar reflector)	220
Appendage Materials (other than sinkers)	35
Rope (1400m)	500
Chain (50m)	250
Shackles (13)	25
Swivels (2)	10
Anchor And Other Weights	110
	1150

Installation of F.A.D.s for small-scale fishermen may be by village groups or fishermens organisations,in which case those individuals who have invested time and money in the device will have some commitment to maintaining it in good order.In such cases construction costs can be minimised if the group is sufficiently well organised to deal with maintenance problems as they occur.This system is described from the Philippines.

Alternatively, small-scale fishermen may be provided with F.A.D.'s by Government or other fisheries development bodies, for instance as part of an overall scheme to increase fisheries sector production. In such a case fisheries sector production. In such a case fishermen will tend to compete rather than cooperate with each other, and may even actively vandalise F.A.D.'s during disputes over fishing entitlements, etc., so F.A.D. builders need to aim for a completely maintenance free and vandal-proof system (even though this will not be the most economical in terms of initial construction costs) if their efforts are not to be wasted. The F.A.D. to be used by Fiji's Fisheries Division during 1982 - 1983 is designed with this aim in mind, and is depicted in Figure 35.

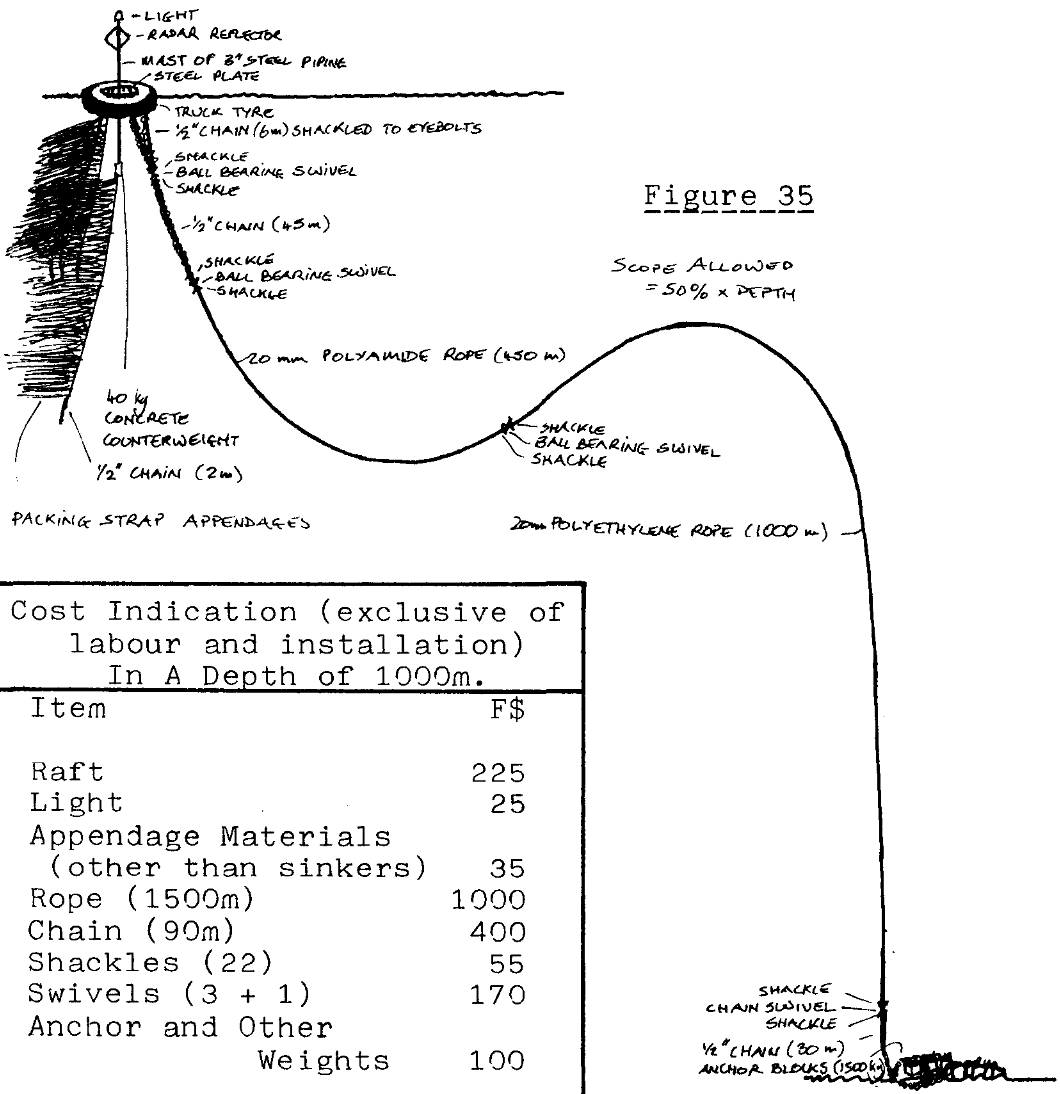
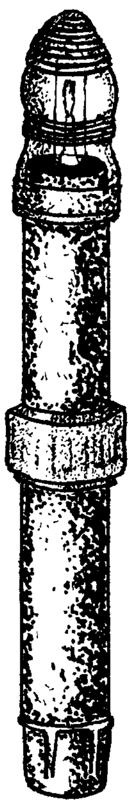


Figure 35

Cost Indication (exclusive of labour and installation) In A Depth of 1000m.	
Item	F$
Raft	225
Light	25
Appendage Materials (other than sinkers)	35
Rope (1500m)	1000
Chain (90m)	400
Shackles (22)	55
Swivels (3 + 1)	170
Anchor and Other Weights	100
	2010

One feature which can never be maintenance free is the light marker used on some F.A.D.'s to enable fishermen to locate them in darkness and as a safety measure in areas of likely marine traffic. This leads to most F.A.D.'s not being equipped with lights. Those which are need to have regular battery replacements by the party responsible for the F.A.D. Lights planned for use in Fiji's Fisheries Division F.A.D's are depicted in Figure 36. These will be fitted in cases where village groups undertake to service them, or on F.A.D.'s close to shipping lanes, in which case they will be serviced by the Division's vessels.



4 cell marine light.
Transistorised, flashing with photo sensor.

Cost: approx F$25 (June 1982)

Supplier:
Scott Plastics Ltd
Vancouver
Canada.

Figure 36

It can thus be seen that F.A.D. system design is widely variable and closely linked to local conditions, which should be carefully examined prior to any F.A.D. programme. Once a system has been decided on and constructed, some thought must be given to placing the F.A.D. in the ocean.

DEPLOYMENT CONSIDERATIONS

Before laying an F.A.D. at any particular site, it is useful to have information on:

1) Incidence of tuna schools in the area;
2) Site depth;
3) Bottom characteristics;
4) Wind and current strength maxima.

Each of these items can contribute to an F.A.D.'s failure to perform. Item 1) refers to the fact that F.A.D.'s serve to aggregate fish already in the vicinity rather than to induce their appearance in areas where they were previously not found. Local mariners can often contribute considerably to the identification of such areas. Depth is often indicated by charts, but fine bottom features are not, and it may be that a site is rendered unsuitable by being steeply sloping or adjacent to a cliff or drop-off. Item 4) is usually completely unknown, and it is therefore not possible to take into account likely force maxima at the proposed site when constructing the F.A.D.

To be confident that the seabed characteristics are suitable for F.A.D. laying, an echo sounder must be used. As site depths are often outside the sounding capacity of normal fathometers, a high power sounder is required. (Some Pacific island Government Fisheries Departments can make use of the echo-sounder available from the U.N.D.P. Regional Fisheries Coordinator in Suva).

Generally flat or only slightly sloping bottoms are to be preferred. Once an apparently suitable bottom site has been located, several transects around the site should be made, to generate bottom profiles extending at least 1 km from the site and thus reveal any unexpected bottom features.

After a suitable site has been identified, final preparations are made for dropping the F.A.D. In many instances it turns out that the site selected has a somewhat different depth than that anticipated, and it may therefore be necessary to modify the mooring line by shortening or lengthening it. The former is preferable, as it is much easier to cut a rope down to size on a boat than it is to start splicing coils together, particularly in rough weather. A useful technique is to connect together rope coils substantially in excess of the maximum number which will be used. In such a case, small sinkers attached to each coil should be used, rather than a large midline sinker, thus avoiding the ropes being over or underweight.

After assembling the system, the F.A.D. can be dropped either raft first, or anchor first. The former technique involves floating the raft then laying the mooring line in a wide circle at the surface. The vessel ends its circle close to the raft and lets go the anchor. This technique is the safer of the two, but has a number of inherent disadvantages. As the anchor takes a considerable amount of time to sink, the whole F.A.D. may drift off-site after release but before setting. (This can be a real problem when placing a raft in a small area of the correct depth, such as on top of a sea mount). Strong currents may deform the surface circle of the mooring line and lead to tangling, and sinkers on the line may cause the central part to attain a considerable depth before the anchor is released, again increasing the likelihood of tangling. These problems have led to this system of raft laying being largely superseded in Fiji by the 'anchor-first' method.

Although it is rather more dangerous (to crew, loose objects on deck, etc.) to have a rope paying out overboard with an extremely heavy object on the end of it, there is much to be said for dropping the anchor first. By taking rope turns around a capstan or samson post the rope payout can be slowed or stopped, and the anchor will soon achieve a fairly low terminal sinking velocity. The boat can remain in the correct position over the seabed until the anchor touches bottom, and the number or rope coils paid out can be counted as a check on the depth, after which the scope can be allowed for before cutting off any excess line and attaching the aggregator. Scope is usually allowed at 20 - 50% of the mooring depth. Problems with rope floating near the surface or sinking irregularly can be avoided, and a greater degree of control can be exercised over the whole procedure. The dangers of this method are only marginally greater than the preceding one provided that precautions are taken to prevent formation of loops of rope and to keep the moving rope away from deck objects and personnel not directly involved in handling the line.

One organisation in Fiji adopted a modification of this method, in that aggregators were prepared in advance by shackling the raft or buoy to one end of a loose coil of rope. The anchor was dropped as described above and after it touched bottom, an additional amount of rope was paid out which, when added to the amount already connected to the aggragator, gave a scope of 30%. The two ropes were then knotted together in a sheet bend, as a time saving convenience, and the aggregator released. Of twelve rafts laid in this manner, eight were known to be missing from their original sites after two weeks. As there was no exceptional bad weather during the two week period, this high loss rate could be attributable to the use of knots in the system, and again emphasises the weakness they induce in the line.

The major operators of F.A.D.'s in Fiji usually lay a number of devices on a single cruise from a moderate sized vessel (120 GRT pole and line vessel: 85 GRT modified lone liner). This requires suitable storage arrangements for the various F.A.D. components, which can be cumbrous (particularly large anchors, as none of the vessels are equipped with heavy lifting gear).

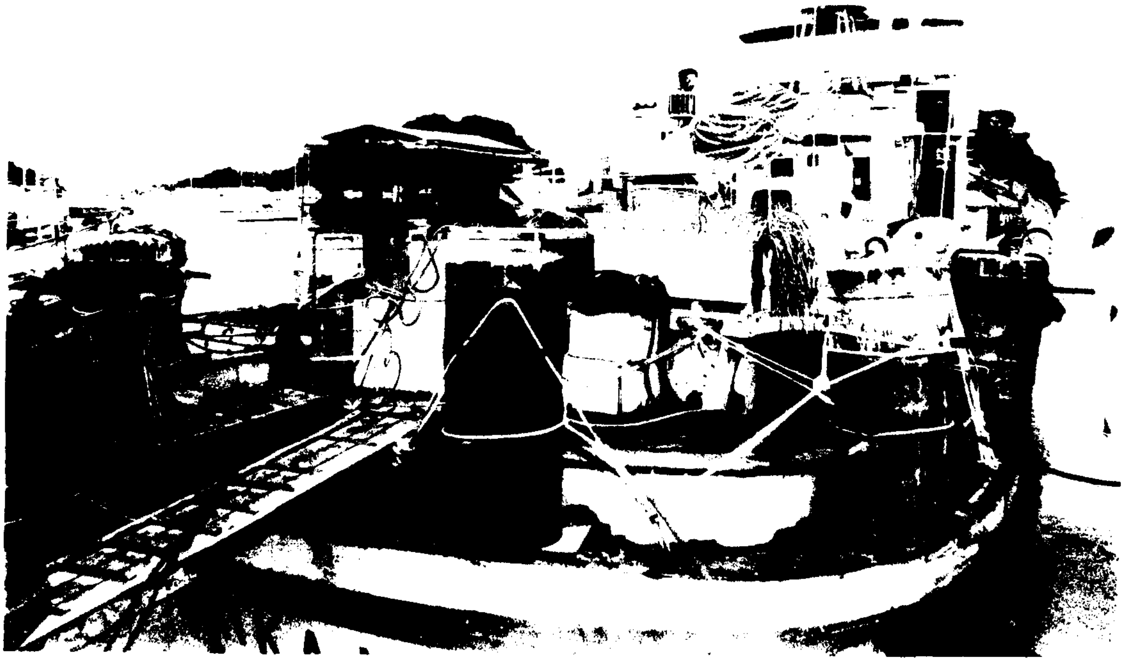


Figure 37
Pole and line vessel 'Ika 1' with anchors and rafts (right background) stowed along fishing platform prior to setting.

The F.A.D. laying pole and line boat, 'Ika 1' uses concrete-filled oildrum anchors which are tied down on the fishing platform at the stern of the vessel. Aggregators are stored amidships and at the bow, on deck or on the fishing platform (see Figure 37). Ropes are prepared in advance and stowed in the bait wells, from where they are paid directly over the side. F.A.D.'s are usually laid raft-first by simply pushing over the side and are of the 'oildrum rocket' type which is intended to be relatively maintenance free. The cost of laying one F.A.D. from the 'Ika 1' is estimated by the operators to be F$500 - 600.

The modified longliner, 'Rainbow Runner', which sets mainly bamboo-raft F.A.D.'s stores these on the deck, deck canopy, and sides with intermediate buoys on top of the cockpit. Anchors, which are set first, are groups of concrete blocks of various sizes. These are stored in holds below deck with intermediate buoys on the cockpit roof. Ropes are laid in coils on deck before paying out through the vessel's long-line door over a davit. Again the installation cost is estimated to be about F$500 per F.A.D.

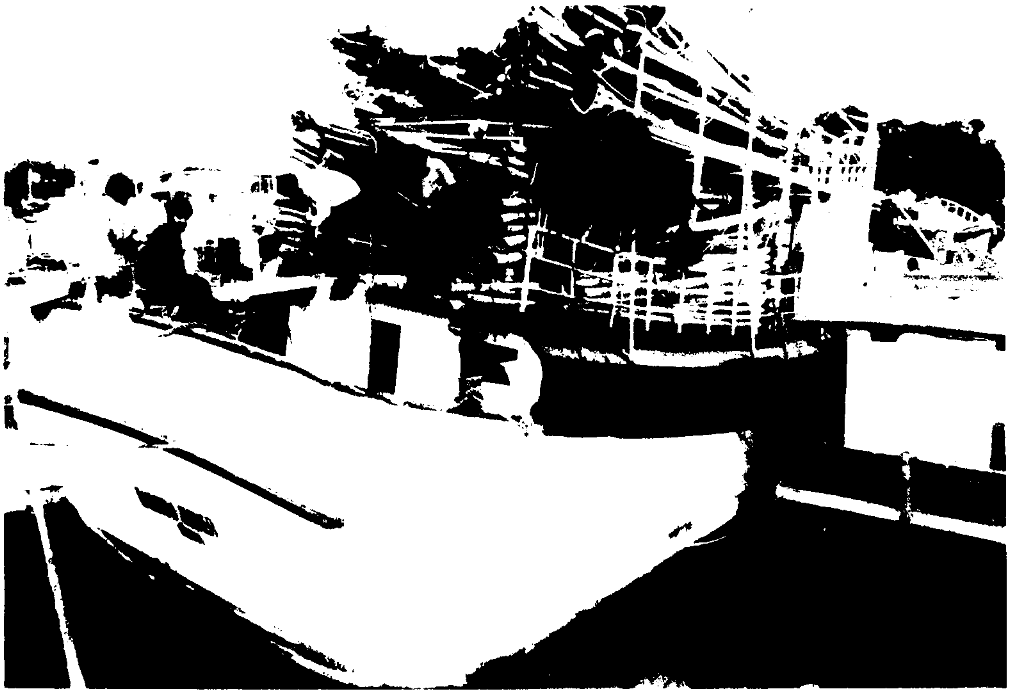


Figure 38
'Rainbow Runner' laden with bamboo-fan rafts prior to setting.

Fisheries Division F.A.D.'s have been laid individually from the 17 m vessel 'Gonedau'. Anchors are placed on a specially arranged platform over the stern, which is chocked up on rollers and held in place by restraining ropes. At the time of dropping the anchor, the restraining ropes and chocks are knocked out, allowing the anchor to slide on the platform into the sea. Longer pieces of rope attached to the boards and rollers of the platform prevent their loss, although care must be taken to avoid these becoming tangled with the mooring line. This system has been variously modified and is most suited to small vessels, with a limited number of crew and deck equipment which is only occasionally involved in the F.A.D. laying.

Most aggregators are light enough to be manhandled overboard by 5 or 6 people. It is usual to stream all the appendages out before releasing the body of the aggregator.

Once a F.A.D. is in the water it is usually fairly difficult to service components already attached. Replacement of appendages is usually done by simply attaching new ones without attempting to remove or repair old ones. Many rafts such as oildrum 'rocket' rafts, are not suitable for standing on and this should be considered if maintenance requirements, such as the necessity to replace batteries for lights or radio emitters, etc., are a feature of the system. Provision for replacing bamboo rafts should be made by incorporating shackles between the raft and the intermediate buoy, which can either be unbolted and reconnected, or to which new shackles can be attached.

Consideration should be given when deploying F.A.D.'s to local shipping regulations, particularly close to harbours or in areas of heavy marine traffic. Some countries have legislation requiring F.A.D.'s to bear night-active lights,or zoning the placement or these potential hazards to shipping. It would appear that the few accidents involving ships and F.A.D.'s have all involved vessels running over a section of the mooring line floating at the surface, rather than collisions. In Fiji these have all been fishing boats operating close to the F.A.D. at dawn, in poor light conditions which prevented the ropes being seen.

EVALUATION OF A F.A.D. DESIGN

During 7 months of 1981 a total of 85 F.A.D.'s of very similar design were installed in Fiji waters. All were anchored with concrete filled oildrums, moored with 16 mm polyethylene rope without upper terminal chains, and carried intermediate buoys to which were attached bamboo fan and bundle rafts of the types shown in Figures 17 and 18. All were laid by the same company, using the same materials and techniques. Observation of the performance and behaviour of these F.A.D.'s allows some general conclusions to be drawn concerning the properties of this particular design, which is illustrated by Figure 32.

The following paragraphs comment in particular on the durability of the design, these comments being based largely on fishing and other records kept by the vessels utilising the F.A.D.'s. It should be noted that these records are often approximate only, and such facts as dates of laying are frequently not logged accurately. Furthermore, the date on which an F.A.D. is lost can never be known accurately.

The interval between an F.A.D.'s last being sighted and the time it is noted as being absent from its site may be long. In such cases it has been assumed here that the F.A.D. was lost on the day preceding its loss being discovered, thus giving an estimate of its maximum possible residence time. In some cases there were no records of F.A.D.'s being visited after laying, and others were still in position when they were last visited. In these cases only the F.A.D's minimum residence time is known, and its subsequent loss may or may not have occured.

Finally, some F.A.D.'s were assumed to have been lost, (even though no definite record of such loss occurred in fishing logs) when they were not included in the next list of current F.A.D. positions prepared by the fishing vessels approximately bi-monthly. These F.A.D.'s are referred to in the following paragraphs as implied losses.

This data base, although imprecise, allows a number of observations based on the following facts:

1) 85 F.A.D.'s were laid between May and December 1981;
2) 22 were recorded as being lost during that period;
3) A further 32 were implied as being lost during the same period;
4) 8 were known to have still been in place in December;
5) For the remaining 23 no visits are recorded and these may have been still in place or lost.

Because it is not known whether the 31 F.A.D.'s of categories 4) and 5) above were lost, or how long they survived after deployment, they have been excluded from the following table, which shows the number of rafts laid, lost, and remaining by month for the 54 rafts known to have been lost.

TABLE 7

Dates of Laying and Loss of 54 F.A.D.'s

	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1) No. of F.A.D.'s lost	26	24	1	0	0	2	1	0
2) Cumulative F.A.D.'s laid	26	50	51	51	51	53	54	54
3) Estimated No. of F.A.D.'s recorded lost	2	1	0	6	6	1	0	6
4) No. of F.A.D.'s implied lost	0	0	11	13	8	0	0	0
5) Cumulative total	2	3	14	33	47	48	48	54
6) No. of F.A.D.'s in situ	24	47	37	18	4	5	6	0

Rearrangement of this data produces the following table illustrating F.A.D. residence times in months for the same 54 F.A.D.'s known to have been lost.

TABLE 8

Maximum Residence Times for 54 F.A.D.'s

	Months after deployment 0	1	2	3	4	5	6	7
Cumulative no. of F.A.D.'s recorded lost	0	3	7	12	18	19	20	22
Cumulative no. of F.A.D.'s implied lost	0	0	10	24	32	32	32	32
Cumulative total no. of F.A.D.'s lost	0	3	17	36	50	51	52	54
Cumulative no. surviving	54	51	37	18	4	3	2	0

Plotted as a graph, the data produces the illustration of F.A.D. attrition shown in Figure 39.

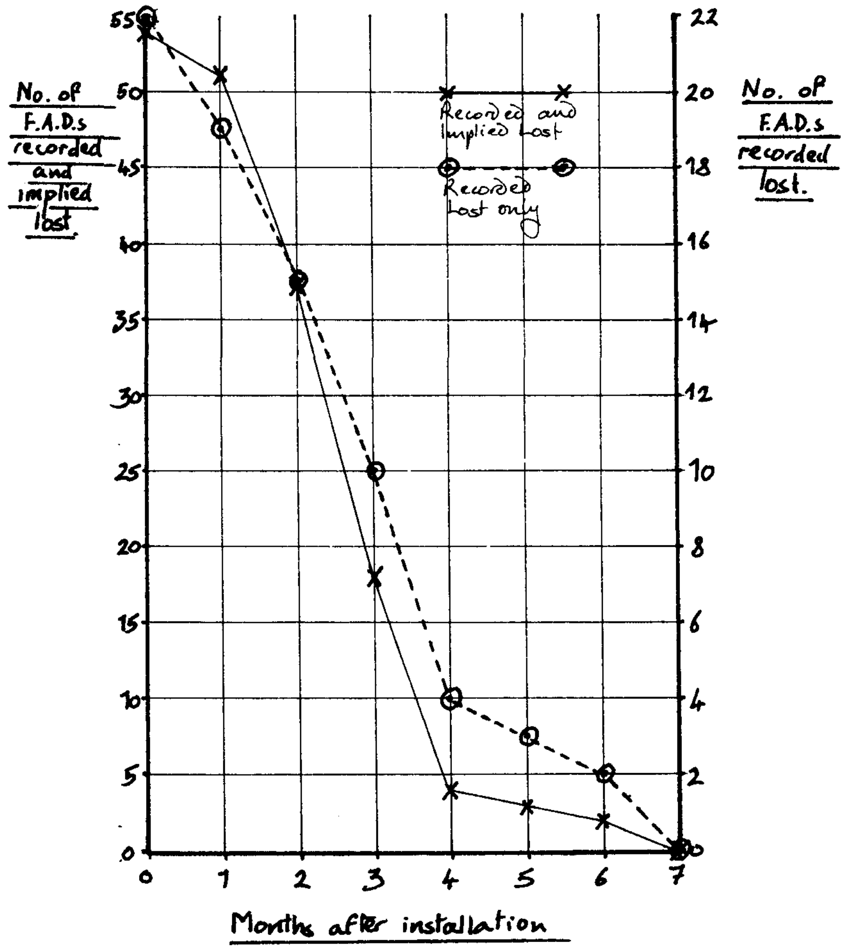


Figure 39
F.A.D. attrition rates.

As can be seen, both indices of F.A.D. attrition rate show a sharp decline after the first month, shallowing out at around four months. Loss of all 54 F.A.D.'s occured within seven months.

The major conclusion to be drawn is that for this particular design, most attrition occurs in the second, third and fourth months after deployment. It is likely that one particular design feature is responsible for this limited life expectancy, and a distinct possibility is the method of attaching the mooring rope directly to the aggregator system without a chain terminal. Another suggestion has been tangling of the mooring line caused by snagging on the midline sinker, as discussed earlier. Elimination of this causal feature would presumably result in a shift of the steeply-graded portion of the graph further to the right, elongating the plateau at the upper left.

As this plot is for only 54 F.A.D.'s which were known to be lost within the 8-month period under discussion we cannot safely extend the conclusions to the extra population of F.A.D.'s whose fate after deployment was uncertain. Minimum residence times were estimated for these 31 rafts, as follows.

TABLE 9

Estimated Minimum Residence Times for 31 F.A.D.'s

	Minimum residence time (months)							
	7+	6+	5+	4+	3+	2+	1+	0+
Number of F.A.D.'s (cumulative)	4	5	7	7	9	13	16	31

As can be seen, at least four were known to be in place seven months after deployment, and an unconfirmed report states that two are in place at the time of writing, fourteen months after the commencement of the period under discussion.

Nevertheless, the pattern of attrition is approximately what one might expect: a 'safe' period, with relatively few F.A.D.'s lost, those which are lost possibly succumbing to storms, unforseen strong currents, or sabotage, etc; followed by a period of much greater F.A.D. loss rate, when components reach their life expectancy; and terminating in another gradual loss period when those abnormally robust F.A.D.'s finally wear out. This type of sigmoid curve, or ogive is frequently seen in manufacturers quality control assessments of batches of the same items which are tested to failure or destruction.

Most F.A.D. deployers would hope to see the ogive for their own particular designs, should it be plotted, much farther to the right and a good deal less steep, and this can doubtless be achieved by increased expenditure on high-quality components. However, this F.A.D's design concentrates on total economy, rather than durability, for reasons already discussed, and readers should not be over-critical of the low life expectancy of these rafts which apparently succeed in their function despite this feature.

A further aspect which can be briefly examined is the rate at which the renewable feature of this F.A.D., i.e. the bamboo aggregator, needs to be replaced. A total of eight aggregator replacements were recorded in fishing logs, although it is certain that many more were carried out. Of these, four were performed one month after installation, one after two months, and three after three months. While no generalisations can be made from this limited data, it does give an indication of the durability of this type of aggregator.

PRODUCTION FROM F.A.D.'S

Colonisation

F.A.D.'s apparently begin to aggregate a wide variety of fishes very rapidly after installation, and, in terms of production for commercial purposes, can be spectacularly effective. A purse seine set in Fiji on a F.A.D. only 6 days old yielded 32 tonnes of tuna. Recruitment of oceanic driftfishes (*Psenes cyanophrys*) has been reported to occur after only 15 minutes, and of 236 individuals representing 8 species after 5 days, to anchored logs (Hunter et al. 1966). Trolling for skipjack was highly successful on the first trip to a F.A.D. in Fiji one week after placement.

Skipjack and yellowfin tunas usually represent the bulk of the fish around any F.A.D., but schools of other pelagic species such as dorado (*Coryphaena hippurus*), frigate tuna (*Euthynnus affinis*), rainbow runner (*Elegatis bipinnulatus*) and scad (*Decapterus macarellus*) also occur, as do more solitary large pelagic individuals such as barracudas, (*Sphyraena* spp.), wahoo (*Acanthocybium solandri*), spanish mackeral (*Scomberomorus* spp.), trevallies (*Caranx* and *Carangoides* spp.), marlins (Istiophoridae) and billfishes (Xiphiidae). A variety of smaller 'bait' species of no commercial significance also occur. Appendix I contains a list of species (which is not intended to be comprehensive) reported from F.A.D.'s in various locations in the Pacific.

Purse seining

F.A.D's were initially deployed in Fiji specifically for purse seining (after attempts to set on free-ranging schools proved unsuccessful) and were only subsequently used by other fishing vessels. Skipjack and yellowfin are the target species, although a substantial by-catch of other tunas, dorado, and rainbow runner is taken. Two purse seiners commenced fishing in June and August 1981 with moderate success, producing 464.7 tonnes at about 6 tonnes/set and 307.6 tonnes at about 10 tonnes/set respectively.

Detailedrecords of all fishing activities are not available and in particular it is not possible to deduce whether those fairly numerous sets which were unsuccessful failed due to technical difficulties on the vessel, absence of fish, or unfamiliarity with the specific techniques required. Of those sets known to be successful, reliable catch data exists for the 38, made by both vessels, included in Table 10 below:

TABLE 10

Catches in a Sample of 38 Successful Purse Seine Sets Made During 1981

Tonnes	0 - 9.9	10 - 19.9	20 - 29.9	30 - 39.9	40 - 49.9	50 - 59.9	60 - 69.9	Total
No. of sets	19	5	8	3	1	1	1	38

As can be seen, the majority of successful sets took less than 10 tonnes although a number of 50 -60 tonne sets were achieved.

When the vessels ceased fishing at the end of the year and left to participate in the New Zealand skipjack fishery, it was clear that some refinement of techniques was required. The vessels returned to Fiji in May and June of 1982 to recommence fishing, but naturally only a limited amount of data is available on these activities at the time of writing. Of the 11 successful sets for which records have so far been returned, catches were as follows:

TABLE 11

Catches in a Sample of 11 Successful Purse Seine Sets Made During 1982

Tonnes	0 - 9.9	10 - 19.9	20 - 29.9	30 - 39.9	40 - 49.9	50 - 59.9	60 - 69.9	Total
No. of sets	4	7	0	0	0	0	0	11

Although only a small amount of data is presented, it may be that catches are tending to increase, despite the fact that these sets were made at the close of the tuna season recognised by pole and line vessels. This is possibly attributable to improved techniques by the fishing vessels, particularly as in recent weeks a number of as yet unconfirmed 40-60 tonne sets have been reported by radio. It thus seems likely that somewhat higher purse seine catches from F.A.D.'s can be anticipated in future years.

The factors influencing a F.A.D.'s aggregating ability are not understood, but it is clear that some are more productive than others. Of 145 tonnes of fish taken from 19 F.A.D.'s by one purse seine vessel, 116 tonnes came from only 5. So far no correlation is apparent between the size of the fish schools detected on the F.A.D.'s and the characteristics of the F.A.D.'s design or environment, although experiments to compare different F.A.D's in similar situations are currently being devised by the purse seine operators.

Pole and Line Fishing

Although reporting of F.A.D.-fishing activities has been incomplete, catch return forms from pole and line vessels in Fiji give some indication of the contribution of F.A.D.'s to their catches, particularly from May 1982 onwards, when they were asked for the first time to estimate on a daily basis what proportion of their catches came from F.A.D.'s. Individual vessel estimates varied widely, some vessels attributing all their catch to F.A.D.'s, some none at all. However, in the first 6 months of 1981 it was estimated that at least 510 tonnes originated from F.A.D.'s, which represents 37.5% of the 1360 tonnes taken by those vessels providing information on F.A.D. fishing activities. In fact this probably represents a large under-estimate of the true contribution of the F.A.D.'s, as there is no doubt that on many occasions references to F.A.D.'s in the catch records were neglected. During May, catch returns estimated that 52% of the 499.4 tonnes taken by the eight vessels which supplied good data originated from F.A.D.'s.

From the daily catch returns for January - June, 186 fishing days were selected from which reasonable estimates of the daily catch on F.A.D.'s could be made, both absolutely and as a percentage of the day's total catch. These data are presented in Tables 12 and 13. As 101 of the days sampled were in May, these have also been examined separately.

TABLE 12

Daily Pole and Line Catch on F.A.D.'s (Tonnes)

Catch	0 - 0.99	1 - 1.99	2 - 2.99	3 - 3.99	4 - 4.99	5 - 5.99	6 - 6.99	7 - 7.99	8 - 8.99	9+	Total
No of days;											
Jan - Jun	47	47	28	22	18	15	4	3	1	1*	186
May only	40	27	11	9	6	5	2	1	-	-	101

* 11 tonnes

The data shows that on 50.5% of the 186 days sampled in January to June, F.A.D. catches experienced were less than two tonnes, this proportion being still higher (66.3%) when the May figures are looked at alone. As most of the data originates from end-of-season months (May and June), a higher porportion of higher-catching days would be expected if the season were examined as a whole. In fact, during May, the average daily catch for the entire fleet was 2.6 tonnes/day: from the data above for May, which represents only a portion of the fishing time of those vessels providing good information on F.A.D. fishing, the average daily catch was 3.5 tonnes, with 2.6 tonnes originating from F.A.D.'s. This may suggest higher production by those vessels fishing F.A.D.'s, but so many other factors, such as the variation in fishing power between vessels, quantity of bait carried, etc., complicate the picture, that this cannot be positively concluded.

F.A.D's generated 81.9% of the 623.5 tonnes caught on the 186 days in question. On a daily basis, their contribution varied between 1.1% and 100% of the catch, according to the pattern shown in Table 13. As can be seen, on the majority of days 100% of the catch came from F.A.D.'s, with a spread of other percentage contributions which suggest opportunistic fishing of free ranging schools by vessels fishing F.A.D.'s or, occasionally, the converse, i.e. visits to F.A.D's by vessels mainly engaged in fishing free ranging schools. However it would appear that those vessels involved in fishing F.A.D.'s do so mainly on a full time basis, and this lends further credence to the contention that F.A.D's are making a higher contribution to catches than reported by the fleet as a whole.

TABLE 13

Percentage Contribution By F.A.D.'s To Daily Pole and Line Catches

% of catch	0-20	20-40	40-60	60-80	80-100	Total
No of days						
Jan - Jun	8	21	18	10	129	186
May only	7	21	11	8	54	101

Trolling

In order to assess the potential of F.A.D.'s for utilisation by fishing methods accessible to small-boat fishermen, trolling trials were carried out from October to December 1981, on two F.A.D.'s, which produced quite different results. Initially trolling (at speeds of 5-8 knots using single 4½" rubber octopus lures rigged on four monofilament lines with double hooks) was conducted around a Fisheries Divison F.A.D. located 2 miles outside a barrier reef passage with disappointing results (47 kg in 12 hours, i.e. 3.9 kg/ fishing hour). Return visits to this F.A.D., which is still in position, have shown that it consistently yields poorly and often carries very small tuna.

Subsequently 153 hours trolling were conducted around a second Fisheries Division F.A.D. some 25 miles away, using the same techniques, which yielded 3978 kg or 26 kg/hour. At the prices then current it was estimated that a fisherman trolling in this manner for a total of about 2½ hours daily (exclusive of travelling times) at dawn and dusk would catch fish worth some F$175, of which sum about half would be needed to cover operating expenses, per day. Subsequent trolling by commercial fishermen has indicated that the catch rates experienced during the survey probably lay in the upper part of the anticipated range, and that the time spent travelling to and from the F.A.D. may be more of a critical factor in determining the likely profit margins than was at first thought, particularly using outboard engines. Catch rates have been variable both between F.A.D.'s and from day to day, and a considerable knowledge of the behaviour of the fish is needed to enable the fisherman to adjust his trolling technique from one day to the next, to take into account changes in the weather and the feeding activity of the school. Nevertheless, it appears likely that F.A.D.'s can support a commercial troll fishery in Fiji if placed in positions accessible from urban centres with ready markets, or processing or distribution facilities. Future deployment of F.A.D's by the Fiji Government is planned for this purpose, and for utilisation by subsistence fishermen in more isolated areas.

Composition of the Catch

The major part of the catch by all three of the fishing methods discussed is skipjack, with a substantial proportion of yellowfin and smaller amounts of other species. During 1980, before the installation of any F.A.D's in Fijian waters, the pole and line fleet took 2238 tonnes of tuna, of which 89.9% were skipjack, 9.9% yellowfin, and 0.2% other species. In 1981 the pole and line catch was 5900 tonnes, and mostly originated from free-ranging schools although some boats fished on F.A.D's late in the year. This year's catch comprised 91.0% skipjack with 8.9% yellowfin and 0.1% other species. By contrast, the yellowfin component of the monthly catches so far taken in 1982 has increased steadily from 7.6% in January to 19.3% in May, this change being attributed to the influence of F.A.D's.

Of the 772 tonnes of tuna taken by purse seiners in 1981, 68.0% was skipjack and 32.0% yellowfin, with less than 0.1% other tuna species. (By-catches of dorado and rainbow runner are not known accurately). Much of the yellowfin consisted of large individuals greater than 20 kg, and this lends support to currently held ideas that a night handline fishery for large yellowfin and bigeye might be developed on F.A.D's.

No data is yet available on purse seine catches in 1982.

During the trolling survey already referred to, daily catches were weighed by species when circumstances permitted. Of a total sample of 2151 kg weighed, 57.9% was skipjack, 33.7% yellowfin, 6.5% dorado, 1.7% wahoo and 0.1% other species. The yellowfin portion of the sample comprised 180 individuals, of which 20 were over 10 kg in weight, including one of 57 kg. The mean weight of the skipjack caught was 2.4 kg.

Table 14 summarises the information discussed in the preceding paragraphs.

TABLE 14

Percentage Composition By Species of Catches By Various Fishing Methods

	Skipjack	Yellowfin	Other
Pole and Line - wild schools (1980)	89.9	9.9	0.2
Pole and Line - wild schools and some F.A.D. (1981)	91.0	8.9	0.1
Pole and Line - wild schools and F.A.D. (Jan - May 1982)	92.4-80.7	7.6-19.3	-
Purse Seine - F,A.D. (1981)	68.0	32.0	-
Trolling - F.A.D. (1981)	57.9	33.7	8.4

During the period in 1981 when F.A.D.'s were first deployed some concern was voiced as to the effects of F.A.D.'s on the size composition of the catch. In particular pole and line operators suggested that purse seining around F.A.D.'s would yield a high proportion of juvenile or undersized fish. Length measurement of skipjack and yellow fin from a number of sources were subsequently compared to test the supposition. This data is presented in Figure 40.

FIG 42: LENGTH-FREQUENCIES OF FIJIAN TUNA CAUGHT BY DIFFERENT METHODS

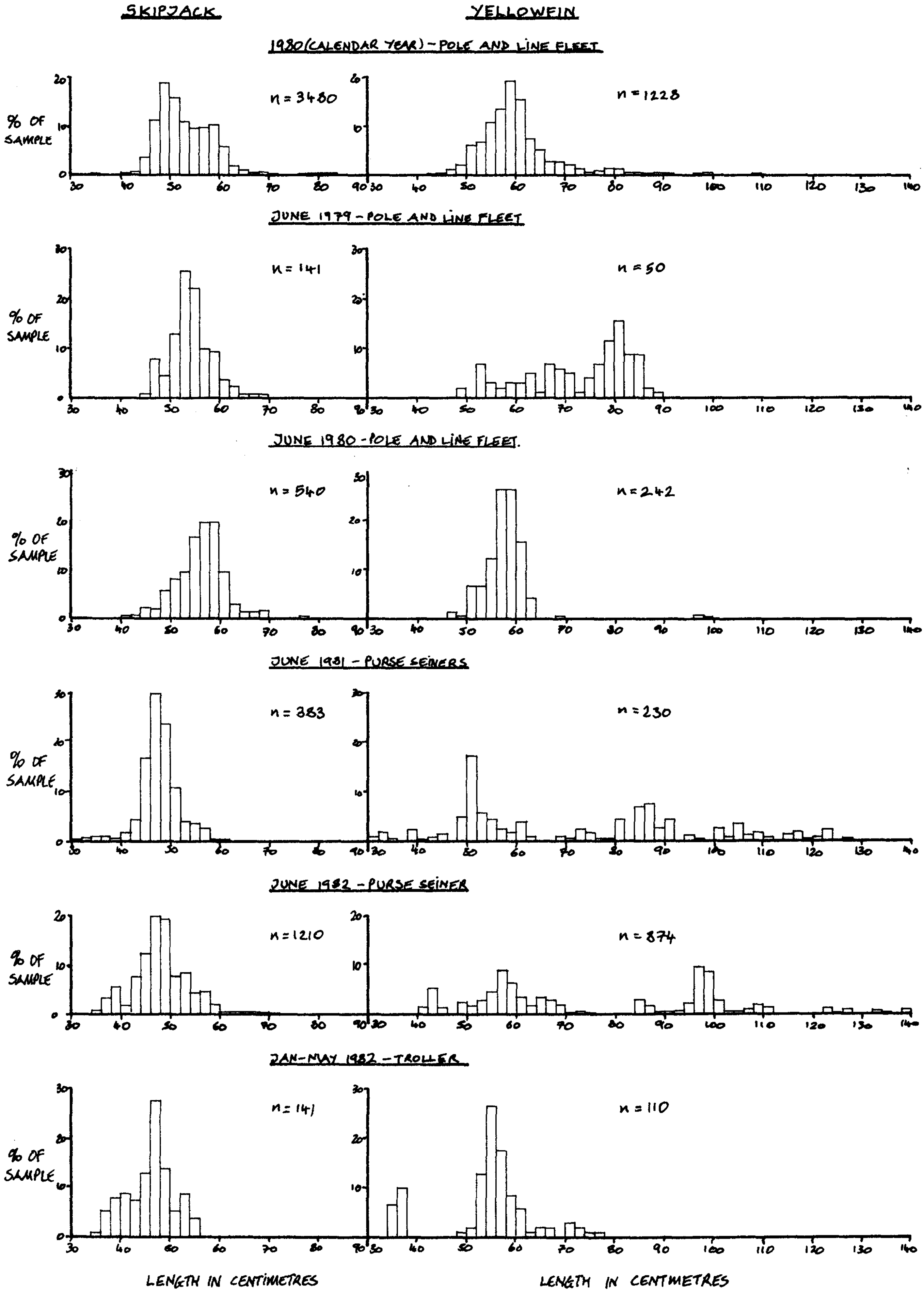


Figure 42 a) and b) give size composition for the whole years pole and line catch in 1980, as an indication of a 'typical' L/F profile. It should be noted that the form of this profile is moderately variable from one year to another (See Fiji Fisheries Division Annual Report , 1980).

Due to limited data availability, a single month, June, has been selected as a basis for comparison of pole and line and purse seine catches. Unfortunately data from the same season is not available for the two fleets, but the similarity in form between the two L/F profiles for pole and line caught skipjack (Figure 42 c) and e)) and the two for purse seine caught skipjack (Figure 42 g) and i)) respectively, suggests that the data is broadly comparable.

An obvious difference in L/F profile can be seen for the two fishing methods, the modes of the purse seine caught distribution (46 - 48 in both years) being noticeably lower that those for the pole and line caught fish (52 - 54 in 1979, 56 - 60 in 1980). The whole of the histogram for purse seine caught fish lies further left than that of the pole and line catch, bearing out the contention that F.A.D. skipjack caught by purse seine tend to be smaller than free-ranging skipjack caught by pole and line. (It is unfortunate that no data currently exists for pole and line caught fish from F.A.D's). Despite their smaller size, very little fish is classified by the cannery as being unacceptably small i.e., less than 4lbs in weight. Skipjack reach this weight at about 44 cm in length. If this size is used as a criterion, then from the data in Figure 42 it appears that about 9.3% of the June 1981 purse seine skipjack catch was $<$4lbs, rising to 19.8% in June 1982.

Figure 42 k) presents data for skipjack trolled by a single commercial fisherman in the first five months of 1982. The general size distribution occupies a similar range to the purse seine caught fish with about 29.1% of the catch being less than 44 cm long.

This data, then, strongly suggests that, in the Fiji situation, F.A.D.'s do tend to produce slightly smaller skipjack than free-ranging schools, although this has yet to be borne out by examining the length/frequency profile of pole and line caught F.A.D. skipjack. This smaller size, however, is not currently considered unacceptable.

The same situation does not occur in yellowfin catches where purse seining produces a much wider range of sizes than do either pole and line fishing or trolling. The L/F profile for pole and line caught yellowfin is in any case much more variable from month to month and year to year than that for skipjack, and examination of a single month's data gives a less than realistic impression of the true picture.

Nevertheless, there is little doubt that purse seining takes a larger proportion of small sized yellow fin than pole and line fishing, but this is outweighed by the even greater amounts of very large fish captured.

OWNERS AND USERS

Since many of the users of F.A.D.'s will frequently be unconnected with its owners (those who were responsible for its original placement), the potential for conflicts is large. Although some national legislation gives owners legal recourse in the event of sabotage to the F.A.D. itself, nowhere is there provision for owners to claim jurisdiction over the fish resources surrounding the F.A.D. In Fiji, this is strictly interpreted as meaning that all Fiji nationals are entitled to fish anywhere in Fiji waters, including on F.A.D.'s (within the provisions of management and licensing regulations which stipulate closed areas or seasons.) In other countries strict adherence to the letter of the law has led to frustrated F.A.D. owners who see themselves being 'robbed' of 'their'fish by other fisherman, taking unilateral steps to preserve what they see as their rights, resulting in incidents which have included shootings and robbery of fish from fishing vessels. The opportunistic users almost invariably react in like fashion, and numerous incidents of F.A.D.'s being cut loose in anger have been reported. In some Pacific countries F.A.D.'s placed by development authorities in order to increase fish production and local prosperity have instead generated bitter feuds. Clearly this aspect of F.A.D. management must be carefully considered in planning F.A.D. programmes.

In cases of potential conflict, a number of solutions can be devised, but all require acceptance and cooperation by each of the parties involved, preferably prior to placing the F.A.D. In Fiji, the national pole and line company contended that purse seining caused that part of the school not captured(sometimes all of it) to sound and not be available to pole and line fishing for several days. Protests based on this supposition, and on the grounds that the purse seine vessels occasionally set on a surface school which had been brought to frenzy by baiting from the pole and line vessel, led to the restriction of purse seine activities to outside a certain area, the purse seiners being allowed to operate within that area only at the discretion of the management staff of the pole and line fleet. This unilateral step was relatively easy to effect in Fiji since the purse seiners are foreign fishing vessels and thus have no recourse to protest, but in a situation where the separate components of a national fishing fleet come into conflict, such a solution may be less easy to enforce, or indeed to justify. Far preferable is an agreement between the parties involved which allows their mutual benefit. Such agreements already in existence vary depending upon the situation. In the Philippines village groups who set F.A.D.'s for their own use claim, and receive, a percentage of the catch taken by purse seine vessels from their devices, and in return maintain the F.A.D.'s. In Fiji, the various pole and line operators will install F.A.D.'s approximately in proportion to their total catches, each F.A.D. being accessible to the entire fleet. In future a common fund may be established for F.A.D. installation, which will be contributed to variously by all operators.

In many cases, user-owner conflicts may be avoided by thoughtful planning of F.A.D. deployment programmes and evaluation of their likely impact on existing and new fisheries.

APPENDIX I

Fish species reported from around F.A.D.s. (Various sources).

SCOMBRIDAE:	Acanthocybium solandri Auxis thazard Euthynnus affinis Euthynnus lineatus Katsuwonus pelamis Scomberomorus commerson Thunnus albacares Thunnus obesus
CARANGIDAE:	Caranx caballus Caranx hippos Caranx marginatus Decapterus macarellus Decapterus punctatus Decapterus sp. Elegatis bipinnulatis Gnathodon speciosus Naucrates ductor Selar crumenophthalmus Seriola colburni Seriola dumerlii Seriola sp.
CORYPHAENIDAE:	Coryphaena equiselis Coryphaena hippurus
ISTIOPHORIDAE:	Makaira indica Makaira nigricans Tetrapturus angustirostris Tetrapturus audax
XIPHIIDAE:	Xiphias gladias
SPHYRAENIDAE:	Sphyraena argentea Sphyraena barracuda
LOBOTIDAE:	Lobotes pacificus
KYPHOSIDAE:	Kyphosus acyurus Kyphosus anulogus Kyphosus cinerascens Kyphosus elegans Kyphosus sp.

APPENDIX I (continued).

MULLIDAE:	Pseudupeneus grandisquamis
MUGILIDAE:	Agonostomus monticola Mugil curema
POLYNEMIDAE:	Polydactylus approximans Polydactylus opercularis
POMACENTRIDAE:	Abedefduf saxatilis Chromis atrilobata
STROMATEIDAE:	Psenes cyanophrys Psenes pacificus
MONACANTHIDAE:	Aluterus monoceros Aluterus scriptus
BALISTIDAE:	Balistes polylepis Canthidermis maculatus
BLENNIDAE:	Blenniolus brevipinnis
(CARCHARHINIDAE:	Carcharhinus azureus Carcharhinus limbatus Carcharhinus spallanzani Galeocerda cuvieri
TRIAKIDAE:	Triaenodon apicalis).

APPENDIX II

Information sources.

The following is a list of people who,in various communications,and by the provision of frequently unpublished literature,provided much of the anecdotal and other information contained in this document.This list is to publish their valuable expertise,and to acknowledge with sincere thanks the assistance which they have provided,many of them unknowingly.

Barwick,R.	Navigator,Nelson Fisheries Ltd., New Zealand.
Bergstrom,M.	Fishing Technologist,F.A.O. Bay Of Bengal Programme,Madras,India.
Clement,I.T.	Fisheries Research Officer,M.A.F., Tauranga,New Zealand.
De San,M.	Associate Expert,F.A.O. Indian Ocean Fisheries Project,Victoria, Seychelles.
Gulbrandsen,O.	F.A.O. Naval Architect,F.A.O. Headquarters,Rome,Italy.
Gonzales,R.	U.N.D.P. Purse-seining Consultant,
Hollyer,J.	Peace Corps Volunteer,Fisheries Division,Apia,Western Samoa.
King Turner,R.	Skipper,purse-seine vessel 'Western Ranger'.
McGregor,M.	Manager,McGregor Consultant And Management Services Ltd.,Lami,Fiji.
Meikle,J.	Assistant Shore Manager,Western Fishing Group,Lami,Fiji.

APPENDIX II (continued).

Morita,A.	Operations Manager,Hokuku Marine Products Ltd.,Suva,Fiji.
Naivalu,S.	Senior Fisheries Assistant, Fisheries Division,M.A.F.,Suva,Fiji.
O'Brien,U.	U.N.D.P. Fishing Consultant, Fisheries Division,Apia,Western Samoa.
Ochi,T.	J.I.C.A. Fisheries Advisor,Fisheries Division,M.A.F.,Suva,Fiji.
Overa,A.	F.A.O. Naval Architect,F.A.O. Headquarters,Rome,Italy.
Patel,R.	General Manager,Ropes Fiji Ltd., Nausori,Fiji.
Philipp,A.	Chief Fisheries Officer,Fisheries Division,Apia,Western Samoa.
Popper,D.	F.A.O. Aquaculture Expert,F.A.O. Headquarters,Rome,Italy.
Reid,P.	Skipper,purse-seine vessel 'Western Pacific'.
Sharma,S.	Senior Fisheries Assistant, Fisheries Division,M.A.F.,Suva,Fiji.
Shomura,R.	Director,N.M.F.S. Honolulu Laboratory,Hawaii.
Southwick,G.	General Manager,Ika Corporation, Suva,Fiji.
Sperling,H.	Regional Fisheries Coordinator, U.N.D.P. Office,Suva,Fiji.
Takali,E.N.	Senior Fisheries Assistant, Fisheries Division,M.A.F.,Suva,Fiji.
Yabaki,A.	Fisherman,Ekubu,Vatulele,Fiji.

APPENDIX III

Bibliography Of Published Reference Material.

1) Anon.,1979-1981:Annual Reports,Fisheries Division, M.A.F.,Fiji.

2) Anon.,1981:'Experimental Rafts Feature In Record W.A. Tuna Catch'.Aust.Fsrs.,Vol.40,No 12,pp 30-32.

3) Anon,1982.Fiji Skipjack Fishery Monthly Bulletins, January - May,1982.Internal Management Documents, Fisheries Division,M.A.F.,Fiji.

4) Anon.,1980.'Fish Attractor For Pelagics Off Sydney'.Aust.Fsrs.,Vol.39,No.3,p 34.

5) Anon., ? .'Payao Purse Seine Fishing'.

6) Anon.,1978.'A Statewide Fish Aggregating System'. Hawaii Dept Of Land And Natural Resources.

7) Anon.,1980.'Tuna Raft Tests'.Fishing News Intnl., May 1980,p 30.

8) Anon.,1980.'Where You Find The Flotsam You Can Also Find The Fish'.Fishing News Intnl.,March 1980,p 26.

9) Bhavani,V.1982.'Fish Aggregation Devices:Information Sources'.Bay Of Bengal Programme, Publication BOBP/INF/2.

10) Clement,I.T.1982.'Fisheries Management Of Fijian Tuna Fisheries'.Report to the Chief Fisheries Officer,Fisheries Division,M.A.F.,Fiji.

11) De San,M.1982.'F.A.D.,Fish Aggregating Device Or Payaos'.F.A.O.,R ome,1982.

12) Hunter,J.R.,1968.'Fishes Beneath Flotsam'.Sea Front,Vol.11,pp 280 - 288.

13) Hunter,J.R. and C.T.Mitchell.,1966.'Association Of Fishes With Flotsam In The Offshore Waters Of Central America'.U.S.Fish.And Wildlife Service Fisheries Bulletin,Vol.66,No.1,pp 13-29.

14) Hunter,J.R. and C.T.Mitchell.,1968.'Field Experiments On The Attraction Of Pelagic Fish To Floating Objects'.J.Cons.perm.Int.Expl.Mer., Vol.31,pp 427 - 434.

APPENDIX III (continued).

15) Kumura,K.,1954.'Analysis Of Skipjack (Katsuwonus pelamis) Shoals In The Waters Of Tokuku Kaiku By Its Association With Other Animals And Objects Based On The Records By Fishing Boats'.Bull.Tokuku Regional Fsrs.Res.Lab.Vol.3, pp 1 - 87.

16) Klima,E.F. and D.A.Wickham.,1971.'Attraction Of Coastal Pelagic Fishes With Artificial Structures'.Trans.Am. Fsrs.Soc.No.1,pp 86-99.

17) Matsumoto,W.M.,1980.'Payao Fishing In The Philippines'. N.M.F.S.,Southwest Fisheries Centre,Honolulu Lab.

18) Matsumoto,W.M.,T.K.Kazama and D.C.Aasted.,1981.'Anchored Fish Aggregating Devices In Hawaiian Waters'.Marine Fsrs.Rev.,Vol.43,No.9,pp 1 - 13.

19) Mitchell,C.T. and J.R.Hunter.,1970.'Fishes Associated With Drifting Kelp,Macrocystis rifera,Off The Coast Of Southern California And Northern California'.Calif.Fish And Game,Vol.4,pp 288 - 297.

20) Murdy,E.O.,1980.The Commercial Harvesting Of Tuna - Attracting Payaos:A Possible Boon For Small-Scale Fishermen'.I.C.L.A.R.M. Newsletter,pp 10 - 13.

21) Ogawa,Y.1966.'Experiment On The Mechanisn Of The Attraction Of An Artificial Reef'.Civil Engineering And Fisheries, Vol.2.

22) Overa,A.,1980.'Report On Experiences With Fish Aggregating Devices Or F.A.D. In Western Samoa'.F.A.O.,Rome.

23) Philipp,A.L.,D.M.Popper and T.C.Teppen.,1980.'Small Scale Pole And Line Fishery In Western Samoa.Report On Preliminary Trials'.Submitted to 12 South Pacific Commission Regional Technical Meeting On Fisheries,Nov.1980.

24) Popper,D.M., ? .Bait Culture Project In Western Samoa. F.A.O.,Rome.

25) Preston,G.L.,1981.'U.N.D.P./Fisheries Division Small Scale Tuna Fishing Project'.Tech.Bull.No.2,Fisheries Division,M.A.F.,Fiji.

26) Senta,T.,1966.'Experimental Studies On The Significance Of Drifting Seaweeds For Juvenile Fishes.1:Experiments With Artificial Drifting Seaweeds'.Bull.Jap.Soc.Sci. Fsrs.Vol.39,pp 639 - 642.

27) Simpson,A.C.,and S.Chikuni.,1976.'Report On Fishing For Tuna In Philippine Waters By F.A.O. Purse Seiners'. F.A.O. South China Sea Programme,Document SCS/76/WP/35, pp 5 - 6.

APPENDIX III (continued).

28) Sund,P.N.,M.Blackburn and F.Williams.,1981.'Tunas And Their Environment In The Pacific Ocean:A Review'.Oceanogr.Mar.Biol.Ann.Rev.,Vol 19,pp 443 - 512.

29) Suzuki.Z.,1981.'Recent Condition Of The Japanese Purse Seine Fishery And The Characteristics Of The Fishery As Seen By The Types Of Schools Fished'.From Proceedings Of The 1980 Tuna Fishery Research Conference,Fsrs.Agency Of Japan Far Seas Fsrs.Res.Lab.pp 252 - 261. (Translation No.61 from Japanese by T.Otsu, N.M.F.S.,S.W.F.C.,Honolulu Lab.,Hawaii.)

30) Yesaki,M.,1977.'Innovations In Harvest Of Pelagic Resources'.Mar.Fsrs.Rev.,pp 14 - 23.